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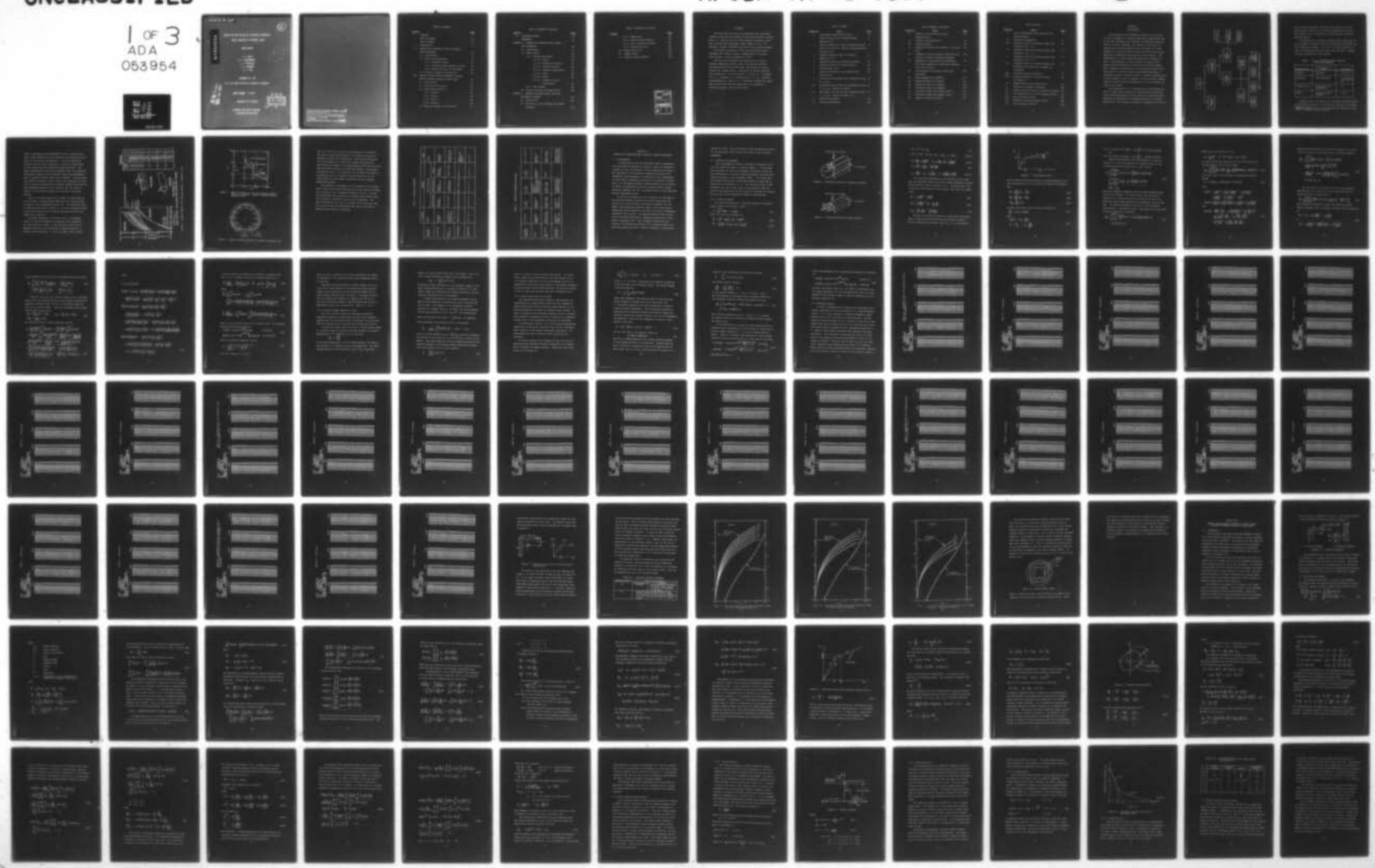

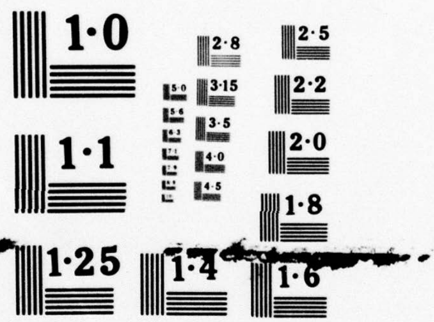

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STUDIES ON THE FAILURE OF STIFFENED CYLINDRICAL SHELLS SUBJECTED TO DYNAMIC LOADS

FINAL REPORT

See 1473 in back

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DECEMBER 31, 1977

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UNIVERSITY OF FLORIDA

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FOREWORD

The work reported herein was performed under joint sponsorship by the Air Force Office of Scientific Research, Bolling AFB, D. C. 20332 and the Air Force Armament Laboratory, Eglin AFB, Florida 32542 under grant number AFOSR 77-3237. Mr. William J. Walker, AFOSR/NA, was the Air Force Program Manager.

The results described in this final scientific report summarize the technical effort accomplished in the period from January 1, 1977 to December 31, 1977.

The work was performed by the University of Florida Graduate Engineering Center, Eglin AFB, Florida 32542 and the Engineering Sciences Department, University of Florida, Gainesville, Florida 32611. University of Florida personnel who contributed to this study were C. A. Ross, R. L. Sierakowski, I. K. Ebcioglu, C. C. Schauble and C. F. Yen. Grateful acknowledgement is made to W. S. Strickland, AFATL/DLYV, Eglin AFB, Florida 32542 for his cooperation and assistance in obtaining computer time for this study.

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SECTION I

INTRODUCTION

One principal task of assessing aircraft vulnerability to blast loadings is to identify appropriate damage modes and to use this information for extension to predicting levels of failure for given loadings. For example, an aircraft in a tactical air or ground situation can be modelled for first analysis as a free free beam or beam on multiple elastic supports when considering large scale structural damage. Consideration of a further localized assessment of damage to a part of the fuselage or control surface can require additional spatial coordinates to define the structural member. Thus a complete identification of the potential damage tolerance levels in aircraft requires appropriate modelling at selected structural component levels. A general representation of this problem is shown in Figure 1 which classifies loading types in a broad sense and identifies the area of primary concern in this report.

Very specifically it is the purpose of the following report to assess those theories most applicable to predicting both elastic and plastic dynamic response of parked aircraft, modelled as stiffened metal cylindrical shells, to lateral blast loads. The structural response so generated can then be

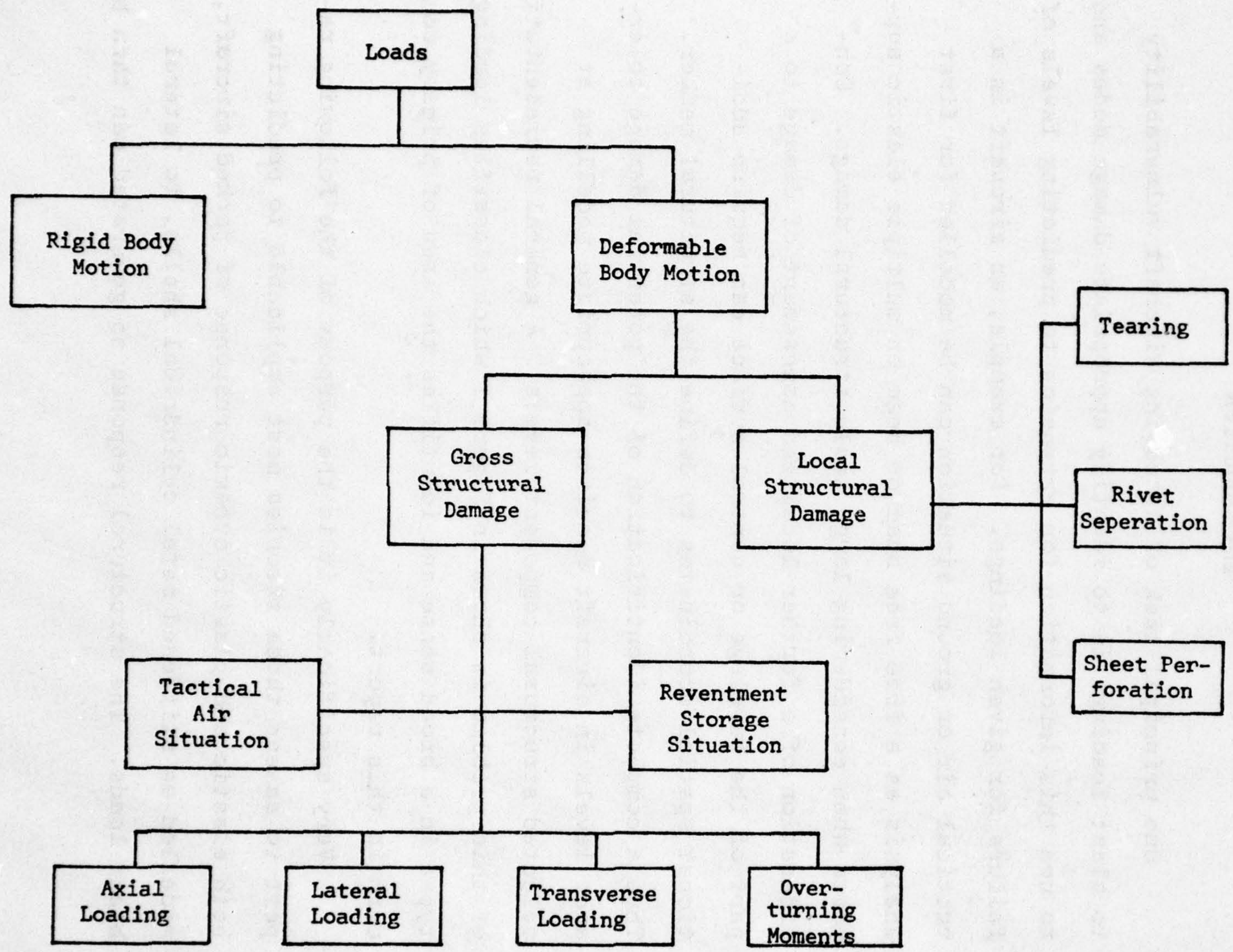


Figure 1. Load/Damage Identification Chart.

used to more extensively study the local effects which ultimately govern failure of a structural configuration, such as, end fixation, rivet connections and overall panel separation and perforation.

In reviewing the literature for analytical predictors for such loadings an extensive search utilizing DOD, DDC, NASA, and GRA filings was surveyed. As a result of this literature review, the following predictive type models of Table I emerged and were considered for modification.

TABLE I. LIST OF CYLINDRICAL SHELL ANALYSES WITH BLAST LOADINGS

Investigator	Classification of Model	References
Schuman	Empirical	1,2,3,4,5
Greenspon	Semi-Analytical	6,7,8,9,10, 11,12,13,14, 15
Lindberg, etc.	Analytical Force Equilibrium	16
Mente	Analytical Modal Analysis	17,18

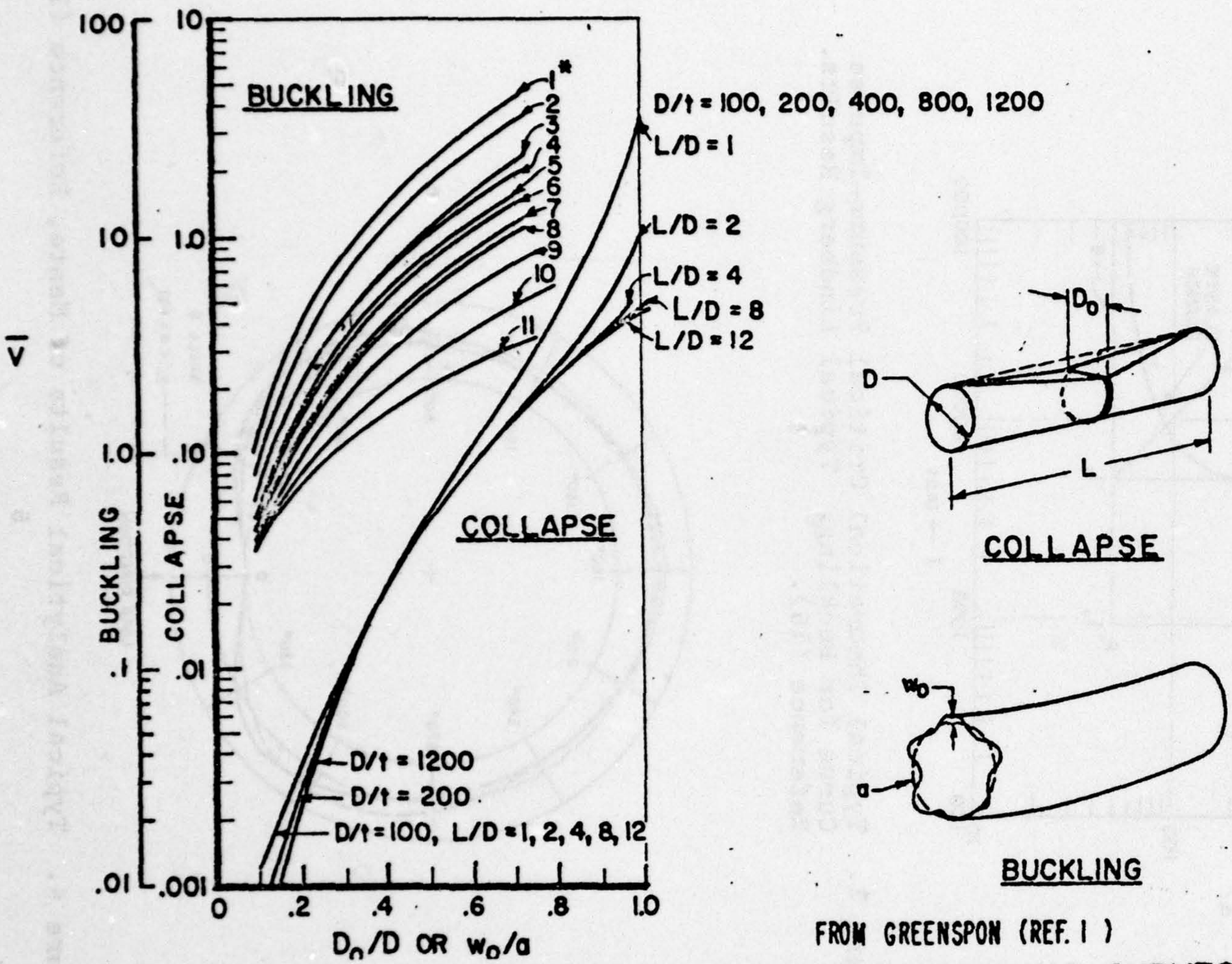
Schuman (1-5)* has tested over six hundred monocoque shell configurations subjected to lateral blast pressures at varying

*Numbers in parentheses () are references and numbers in brackets [] represent equation numbers.

stand off distances and quantified his work in tabular form. These tests represent the most exhaustive experimental studies found by the current investigators. The data obtained by Schuman has been used by Greenspon to check his theory which in this report has been labelled as semi-analytical. The above classification was made to emphasize that the analytical development requires some information based upon experimental data to quantify failure modes and/or loadings. The analytical code DEPROP developed by Mente and Lee (18) represents an ambitious analytical representation directed towards predicting the time dependent response of the structure and thus obtain a history of the response leading up to ultimate structural failure.

Each of the above approaches is useful in predicting certain features of experimentally observed shell response which is shown in the accompanying Figures 2-4. The particular type of response predicted is inherent in the basic assumptions within the scope of each of the theories presented and these are summarized in Table II.

The major objective of this study was to investigate effects of axial stiffening of cylindrical shell subjected to transverse blast loads. It was decided the most direct approach would be one of modifying an existing model(s) to include axial stiffening. In that the DEPROP code of Mente



FROM GREENSPON (REF. 1)

BUCKLING

CURVE NO.*	D/t	L/D
1	1200	1
2	800	1
3	400	1
4	1200	2
5	200	1
6	800	2
7	100	1
8	1200	4
	800	4
	400	2
9	1200	8
	400	4
	200	2
	100	2
10	800	8
	400	8
	200	4
	100	4
11	800	12
	400	12
	200	8
	100	12

POST FAILURE COLLAPSE AND BUCKLING CURVES

Figure 2. Typical Results for Greenspon Method. Reference (13).

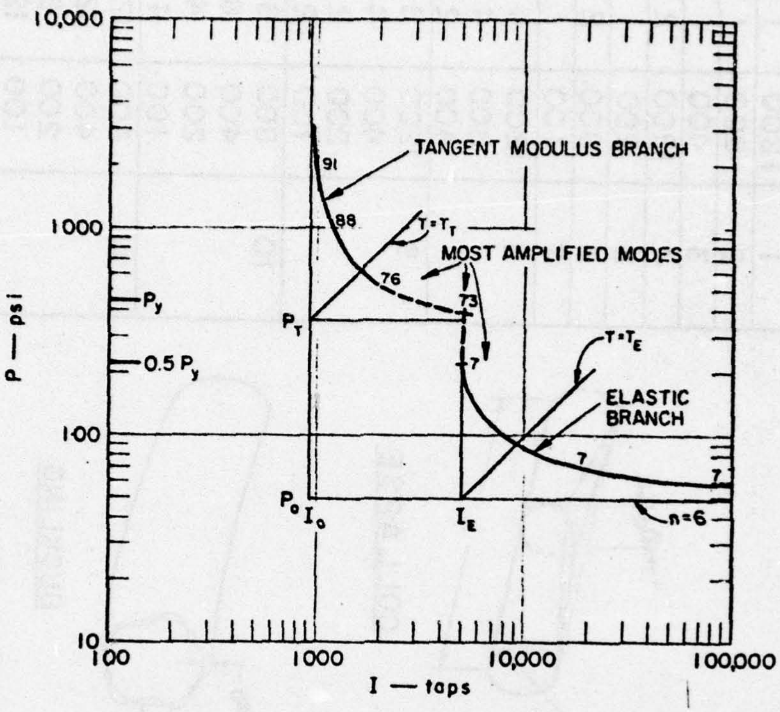


Figure 3. Typical Theoretical Critical Pressure-Impulse Curve for Buckling. Typical Lindberg Results. Reference (16).

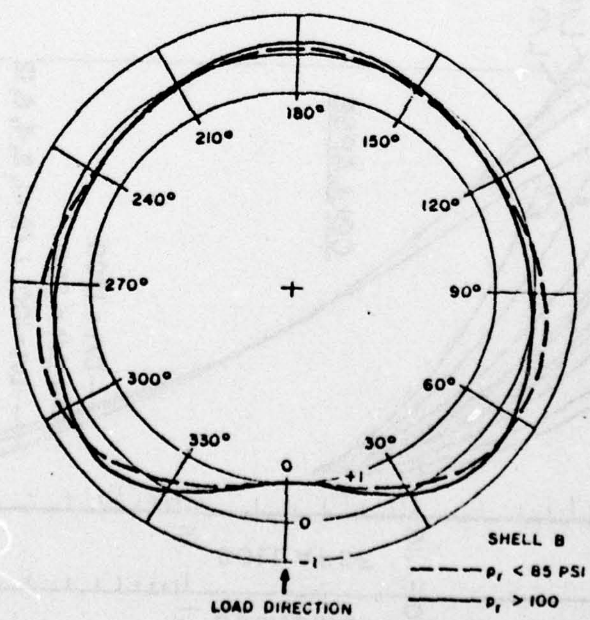


Figure 4. Typical Analytical Results of Mente, Reference (17).

and Lee (17,18) was on file it was selected to be modified and serve as the detailed method for calculating localized stresses, strains, and deflections. The method of Greenspon (6-15) was chosen as a 'first-cut' design type predictor. Both methods are based on an energy approach and were used with some reasonable accuracy in predicting damage in unstiffened cylindrical shells. The selection of only these two models to be modified in no way reflects upon the usefulness of the other models, but was simply considered the most expedient engineering method.

The analytical development for the response of the cylindrical shell with axial stiffening for the two separate methods will be given in the following Sections II and III. In that the modification must parallel the original basic method only the stiffened or modified version will be developed. The basic unstiffened case will be included in the stiffened case and a solution for the unstiffened case may be obtained by assuming zero number of stiffeners.

TABLE II. ANALYTICAL ASSUMPTIONS

	Greenspon	Lindberg			Mente
Analytical Approach	Energy	Force Equilibrium			Energy
		Tangent Modulus	Strain Reversal	Elastic	
Failure Mode	Buckling/ Collapse	Buckling (High Order)	Buckling (Intermediate)	Buckling (Low Order)	Buckling/ Collapse
Shell Description	At Buckling or Collapse in Plastic Region	Plastic Region	In Elastic and Plastic Region	Elastic Region	In Elastic and Plastic Region
Displacements	Large Radial Only	Small Radial Only	Small Radial Only	Small u, v, w	Large u, v, w (Novozhilov Theory)
Deformations	$w \neq 0$, $u,v = 0$	$w \neq 0$, $u,v = 0$	$w \neq 0$, $u,v = 0$	$u,v,w \neq 0$	$u,v,w \neq 0$

TABLE II. ANALYTICAL ASSUMPTIONS (Concluded)

Functional Dependence	$w = w(x,\theta)$	$w = w(\theta)$ $w \neq w(x)$	$w = w(\theta)$ $w \neq w(x)$	$w = w(\theta)$ $w \neq w(x)$	$u,v,w = g(x,\theta,t)$
Forces	Bending and Membrane	Bending and Membrane	Bending and Membrane Membrane Constant Bending Trigonometric Varying	Bending and Membrane	Bending and Membrane
Constitutive Eqs.	Elastic Comp. Plastic Incomp.	Elastic Comp. Plastic Comp.	Elastic Comp. Plastic Comp.	Elastic	Elastic Comp. Plastic Incomp.
Plasticity Considered	Deformation Theory Loading Only	Deformation Theory Loading Only	Incremental Theo. Kinematic Harden. Loading-Unloading	--	Deformation Theo. Kinematic Harden. Loading-Unloading

SECTION II

EXTENSION OF GREENSPON SHELL THEORY TO INCLUDE STIFFENERS

2.1 Introduction

In this section, the semi-analytical model of Greenspon (15), previously described in Section I, has been extended to include the use of stiffeners in blast loaded shell analysis. The selection of this analytical approach for further consideration and development is based upon (a) its adaptability to facilitate an engineering approach for inclusion of stiffeners, (b) the models realistic characterization of the principal modes of deformation occurring (collapse and/or circumferential buckling) and (c) the relative ease of characterizing failure from design curves.

It should be remarked that the inclusion of stiffeners in any existing analytical development should necessitate the introduction of anisotropic constitutive equations into the formal shell governing equations which in turn would lead to complicated coupled equations involving the shells displacement coordinates for solution. The approach adopted here, as mentioned, has been based upon an engineering approach as introduced in reference (15). This technique incorporates the influence of stiffness anisotropy in an uncoupled manner into the energy equations which is readily adaptable to Greenspon's

analytical model. This development, which incorporates details of the unstiffened shell analysis is given in the following paragraphs.

2.2 Analytical Development

This development is based on the work of Greenspon (6-15) for the cylindrical shell as shown in Figure 5. The development parallels the case of unstiffened cylindrical shells and the modifications to include stiffening effects are shown with broken underlines in the respective terms. It is noted that full credit for the basic unstiffened method is given and is documented in References 6 to 15. The choice of words in the following text may in many cases closely parallel those as given in the references and when given are selected for clarity and for lack of more descriptive method of presentation.

2.2.1 Potential Energy

The work of deformation, V per unit volume of an elastic-plastic body can be written (13,14),

$$V = \int_0^{e_i} \sigma_i \, de_i + K_v \Theta_v^2 , \qquad [1]$$

where K_v is the bulk modulus and

$$\sigma_i = (\sigma_x^2 - \sigma_x \sigma_y + \sigma_y^2 + 3\tau_{xy}^2)^{\frac{1}{2}} , \qquad [2a]$$

$$e_i = \frac{2}{\sqrt{3}}(\epsilon_x^2 + \epsilon_x \epsilon_y + \epsilon_y^2 + \tfrac{1}{4}\gamma_{xy}^2)^{\frac{1}{2}} , \qquad [2b]$$

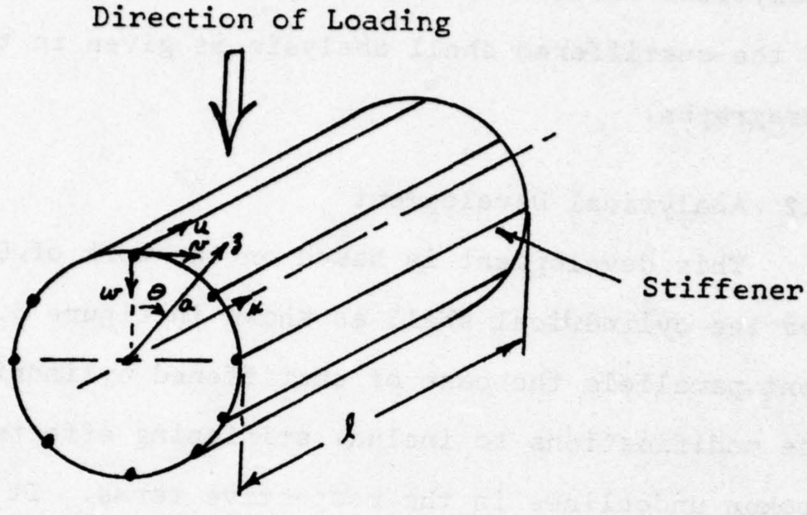


Figure 5. Coordinate System for Greenspon Analysis.

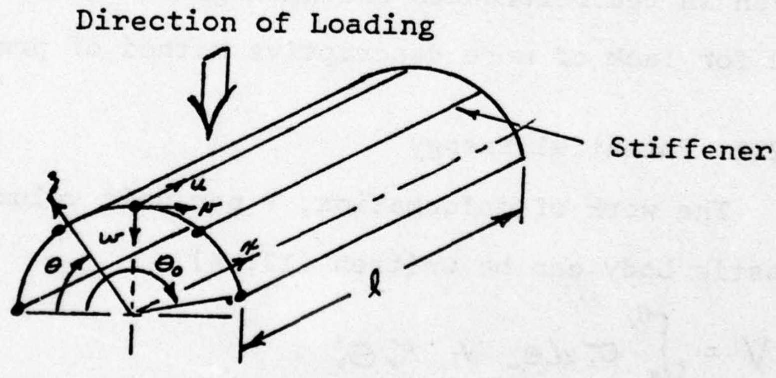


Figure 6. Coordinate System for Mente Analysis.

$$\theta_v = \epsilon_x + \epsilon_y + \epsilon_z , \qquad [3]$$

$$\epsilon_x = \epsilon_1 - z K_1 , \; \epsilon_y = \epsilon_2 - z K_2 , \; \gamma_{xy} = \gamma - 2z\tau , \qquad [4a,b,c]$$

$$\epsilon_1 = \frac{\partial u}{\partial x} + \frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2 , \; \epsilon_2 = \frac{1}{a}\frac{\partial v}{\partial \theta} - \frac{w}{a} + \frac{1}{2}\left(\frac{\partial w}{a\partial \theta}\right)^2 , \qquad [5a,b]$$

$$\gamma = \frac{\partial v}{\partial x} + \frac{1}{a}\frac{\partial u}{\partial \theta} + \frac{\partial w}{\partial x}\frac{\partial w}{a\partial \theta} , \qquad [5c]$$

$$K_1 = \frac{\partial^2 w}{\partial x^2} , \; K_2 = \frac{1}{a^2}\frac{\partial^2 w}{\partial \theta^2} , \; \tau = \frac{1}{a}\frac{\partial^2 w}{\partial x \partial \theta} + \frac{1}{a}\frac{\partial v}{\partial x} . \qquad [6a,b,c]$$

For very large deformations under intense lateral loading the midsurface strain involving w should probably be greater than the linear terms involving u and v. Assuming that u and v and their derivatives are much smaller than w and its derivatives,

$$\epsilon_x = \frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2 - z\frac{\partial^2 w}{\partial x^2} \qquad [7a]$$

$$\epsilon_y = \frac{1}{2}\left(\frac{\partial w}{a\partial \theta}\right)^2 - \frac{w}{a} - \frac{z}{a^2}\frac{\partial^2 w}{\partial \theta^2} \qquad [7b]$$

$$\gamma_{xy} = \frac{\partial w}{\partial x}\frac{\partial w}{a\partial \theta} - \frac{2z}{a}\frac{\partial^2 w}{\partial x \partial \theta} \qquad [7c]$$

Further, the material response is restricted to one that obeys an elastic-linear hardening law as shown in Figure 7. For an incompressible material, that is, $\phi = 0$, the stresses

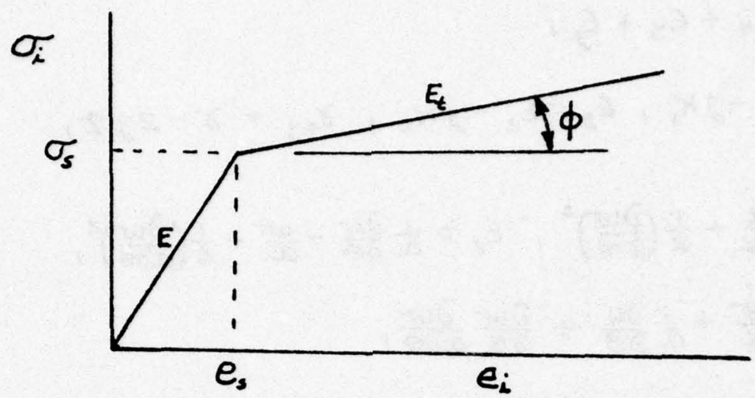


Figure 7. Stress-Strain Curve.

can be written in terms of strains, following Reference (15), for a Poisson ratio of 0.5 for both the elastic and plastic case.

$$\sigma_x = \frac{4\sigma_i}{3e_i}\left(\epsilon_x + \frac{\epsilon_y}{2}\right), \qquad [8a]$$

$$\sigma_y = \frac{4\sigma_i}{3e_i}\left(\epsilon_y + \frac{\epsilon_x}{2}\right), \qquad [8b]$$

$$\tau_{xy} = \frac{\sigma_i}{3e_i}\gamma_{xy}, \qquad [8c]$$

in which the stress-strain law can be written as,

$$\frac{\sigma_i}{e_o} = E\left[1-\omega(e_i)\right], \qquad [9]$$

where

$$\omega(e_i) = \lambda\left(1-\frac{e_s}{e_i}\right),$$

$$\lambda = 1 - \frac{E}{E_t}, \quad E_t = \frac{d\sigma_i}{de_i}. \qquad [10]$$

For the elastic case $\omega(e_i) = \lambda\left(1-\frac{e_s}{e_i}\right) = 0,\ e_i < e_s,\ \sigma_i < \sigma_s,$

and

for the plastic case $\omega(e_i) = \lambda\left(1-\frac{e_s}{e_i}\right),\ e_i > e_s,\ \sigma_i > \sigma_s.$

Substituting Equation [10] into Equation [1] for the case of $\phi = 0$, the work done by the internal forces of the stiffened cylindrical shell (pg. 5, Ref. 13) is

$$V = \int_0^L \int_0^{2\pi} \int_{-\frac{t}{2}}^{+\frac{t}{2}} \int_0^{e_i} E e_i \left[1-\lambda\left(1-\frac{e_s}{e_i}\right)\right] de_i\, a\, d\theta\, dx\, dz$$

$$+ \underline{\sum_{i=1}^{N} \int_0^L \iint_{A_i} \int_0^{e_i} E e_i \left[1-\lambda\left(1-\frac{e_s}{e_i}\right)\right] de_i\, dx\, dA} \qquad [11]$$

$$= V_{sh} + \underline{V_{st}}$$

where A_i indicates integration over the cross sectional area of the ith stiffener. The first term on the left side of Equation [11] is associated with the work of the shell V_{sh} while the second term represent the contribution of the stiffener. The dotted underlined terms refer to the stiffener contributions. Considering Figure 1 and Equations [9] and [10] V_{sh} may be obtained in the form:

$$V_{sh} = \int_0^L \int_0^{2\pi} \int_{-\frac{t}{2}}^{+\frac{t}{2}} \left[\frac{E e_i^2}{2}(1-\lambda) + E\lambda e_s e_i\right] a\, d\theta\, dx\, dz \qquad [12]$$

$$- E\lambda e_s^2 \pi a L t.$$

Rewriting e_i of Equation [26] as

$$e_i = \frac{2}{\sqrt{3}}\sqrt{\xi}\ , \quad \xi = \varepsilon_x^2 + \varepsilon_x\varepsilon_y + \varepsilon_y^2 + \frac{1}{4}\gamma_{xy}^2\ ,$$

and substituting into Equation [12] the work done by the internal forces of the shell becomes

$$V_{sh} = \int_0^L\int_0^{2\pi}\int_{-\frac{t}{2}}^{\frac{t}{2}}\left[\frac{E}{2}(1-\lambda)\frac{4}{3}\xi + \frac{E\lambda e_s}{\sqrt{3}}2\sqrt{\xi}\right]a\,d\theta\,dx\,dz - E\lambda e_s^2\pi a L t. \qquad [13]$$

The strain term ξ when expanded using Equation [5a,b,c] becomes

$$\xi = \alpha(x,\theta) + z^2\beta(x,\theta) + z\gamma(x,\theta) \qquad [14]$$

where

$$\alpha(x,\theta) = \frac{1}{4}\left(\frac{\partial w}{\partial x}\right)^4 + \frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\left(\frac{\partial w}{a\partial\theta}\right)^2 - \frac{1}{2}\frac{w}{a}\left(\frac{\partial w}{\partial x}\right)^2 + \frac{1}{4}\left(\frac{\partial w}{a\partial\theta}\right)^4 - \frac{w}{a}\left(\frac{\partial w}{a\partial\theta}\right)^2 + \left(\frac{w}{a}\right)^2$$

$$\beta(x,\theta) = \left(\frac{\partial^2 w}{\partial x^2}\right)^2 + \frac{1}{a^2}\left(\frac{\partial^2 w}{\partial x^2}\right)\left(\frac{\partial^2 w}{\partial\theta^2}\right) + \frac{1}{a^4}\left(\frac{\partial^2 w}{\partial\theta^2}\right)^2 + \frac{1}{a^2}\left(\frac{\partial^2 w}{\partial x\partial\theta}\right)^2$$

and

$$\gamma(x,\theta) = -\left(\frac{\partial w}{\partial x}\right)^2\frac{\partial^2 w}{\partial x^2} - \frac{1}{a}\frac{\partial^2 w}{\partial\theta^2}\left(\frac{\partial w}{a\partial\theta}\right)^2 + \frac{2}{a^2}\frac{\partial^2 w}{\partial\theta^2}\frac{w}{a} - \frac{1}{2a^2}\left(\frac{\partial w}{\partial x}\right)^2\frac{\partial^2 w}{\partial\theta^2} - \frac{1}{2}\frac{\partial^2 w}{\partial x^2}\left(\frac{\partial w}{a\partial\theta}\right)^2 + \frac{w}{a}\frac{\partial^2 w}{\partial x^2} - \frac{1}{a}\frac{\partial^2 w}{\partial x\partial\theta}\frac{\partial w}{\partial x}\frac{\partial w}{a\partial\theta} \qquad [15]$$

Substituting Equations [14] and [15] into Equation [13] the potential energy for the shell without stiffeners becomes,

$$V_{sk} = \int_0^L \int_0^{2\pi} \Big\{ \frac{2}{3} E(1-\lambda)\left(t\alpha + \frac{t^3}{12}\beta\right) a\,d\theta\,dx$$

$$+ \frac{2\lambda E e_s}{\sqrt{3}} \Big[\frac{(2\beta z + \gamma)\sqrt{\alpha + \gamma z + \beta z^2}}{4\beta}$$

$$+ \frac{4\alpha\beta - \gamma^2}{8\beta\sqrt{\beta}} \sinh^{-1}\left(\frac{2\beta z + \gamma}{\sqrt{4\alpha\beta - \gamma^2}}\right)\Big]_{-\frac{t}{2}}^{\frac{t}{2}} \Big\} a\,d\theta\,dx \qquad [16]$$

$$- E\lambda e_s^2 \pi a L t.$$

The work done by the internal forces in the stiffener represented by the second term on the right hand side of Equation [11] may be rewritten as

$$V_{st} = \sum_{i=1}^{N} \left\{ \int_0^L \int_{A_i} \left[\frac{E e_i}{2}(1-\lambda) + E\lambda e_s e_i \right] dx\,dA - \frac{E\lambda e_s^2}{2} L A_i \right\} \qquad [17]$$

The stiffener is assumed to resist only axial and radial forces, therefore, for a stiffener, Equation [7a] is expressed as

$$e_i = \varepsilon_x = \frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2 - z\frac{\partial^2 w}{\partial x^2}$$

or [18]

$$e_i^2 = \frac{1}{4}\left(\frac{\partial w}{\partial x}\right)^4 - z\left(\frac{\partial w}{\partial x}\right)^2 \frac{\partial^2 w}{\partial x^2} + z^2\left(\frac{\partial^2 w}{\partial x^2}\right)^2$$

Using Equations [17] and [18] the stiffener work term becomes

$$V_{st} = \sum_{i=1}^{N} \left\langle \int_0^L \left\{ \frac{E(1-\lambda)}{2}\left[\frac{1}{4}\left(\frac{\partial w}{\partial x}\right)^4 A_i + \frac{\partial^2 w}{\partial x^2}\int_{A_i} z^2 dA_i\right] + \frac{E\lambda e_s}{2}\left(\frac{\partial w}{\partial x}\right)^2 A_i \right\} dx - \frac{E\lambda}{2} e_s^2 L A_i \right\rangle . \qquad [19]$$

Equation [11] gives the potential energy of the stiffened shell and it was obtained from the stress-strain relations [8] assuming a Poisson's ratio of 0.5 in the plastic region as well as the elastic region. Using the following stress-strain relations for plane stress,

$$\sigma_x = \frac{E}{1-\nu^2}\left(\varepsilon_x + \nu\varepsilon_y\right) , \quad \sigma_y = \frac{E}{1-\nu^2}\left(\varepsilon_y + \nu\varepsilon_x\right), \qquad [20]$$
$$\tau_{xy} = \frac{E}{2(1+\nu)}\gamma_{xy},$$

the combined potential energy expression becomes

$$V = \frac{E(1-\lambda)taL}{2(1-\nu^2)}\int_0^1\int_0^{2\pi}\bar{\alpha}\,dx'd\theta + \frac{E(1-\lambda)taL}{6(1-\nu^2)}\int_0^1\int_0^{2\pi}\bar{\beta}\,dx'd\theta$$
$$+ \frac{\lambda E e_s taL}{\sqrt{3}}\int_0^1\int_0^{2\pi}\left\{\frac{(2\bar{\beta}+\bar{\gamma})\sqrt{\bar{\alpha}+\bar{\gamma}+\bar{\beta}}}{4\bar{\beta}} + \frac{(4\bar{\alpha}\bar{\beta}-\bar{\gamma}^2)}{8\bar{\beta}\sqrt{\bar{\beta}}}\sinh^{-1}\frac{(2\bar{\beta}+\bar{\gamma})}{\sqrt{4\bar{\alpha}\bar{\beta}-\bar{\gamma}^2}}\right.$$
$$\left. -\left[\frac{(-2\bar{\beta}+\bar{\gamma})\sqrt{\bar{\alpha}-\bar{\gamma}+\bar{\beta}}}{4\bar{\beta}} + \frac{(4\bar{\alpha}\bar{\beta}-\bar{\gamma}^2)}{8\bar{\beta}\sqrt{\bar{\beta}}}\sinh^{-1}\frac{(-2\bar{\beta}+\bar{\gamma})}{\sqrt{4\bar{\alpha}\bar{\beta}-\bar{\gamma}^2}}\right]\right\} dx\,d\theta$$
$$+ \sum_{i=1}^{N}\left\langle \int_0^1 \left\{ \frac{E(1-\lambda)L}{2}\left[\frac{1}{4}\left(\frac{w_0}{a}\right)^4\left(\frac{a}{L}\right)^4\left(\frac{\partial f}{\partial x'}\right)^4 A_i + \left(\frac{w_0}{a}\right)^2\left(\frac{a}{L}\right)^2\left(\frac{\partial^2 f}{\partial x'^2}\right)\frac{I_i}{L^2}\right]\right.\right.$$
$$\left.\left. + \frac{E\lambda e_s L}{2}\left(\frac{w_0}{2}\right)^2\left(\frac{a}{L}\right)^2\left(\frac{\partial f}{\partial x'}\right)^2 A_i\right\} dx' - \frac{E\lambda e_s^2 L A_i}{2}\right\rangle - E\lambda e_s \pi a L t , \qquad [21]$$

where

$$w = w_0 f(x',\theta)$$

$$\bar{\alpha}(x',\theta) = \alpha_e(x',\theta) = \left(\frac{w_0}{a}\right)^4\left(\frac{a}{L}\right)^4\left(\frac{1}{4}\right)\left(\frac{\partial f}{\partial x'}\right)^4 + \left(\frac{w_0}{a}\right)^4\left(\frac{a}{L}\right)^2\left(\frac{1}{2}\right)\left(\frac{\partial f}{\partial x'}\right)^2\left(\frac{\partial f}{\partial \theta}\right)^2$$

$$-\nu\left(\frac{w_0}{a}\right)^3\left(\frac{a}{L}\right)^2 f\left(\frac{\partial f}{\partial x'}\right)^2 + \frac{1}{4}\left(\frac{w_0}{a}\right)^4\left(\frac{\partial f}{\partial \theta}\right)^4 - \left(\frac{w_0}{a}\right)^3 f\left(\frac{\partial f}{\partial \theta}\right)^2 + \left(\frac{w_0}{a}\right)^2 f^2,$$

$$\bar{\gamma}(x',\theta) = \frac{t}{2}\gamma_e(x',\theta) = -\left(\frac{w_0}{a}\right)^3\left(\frac{a}{L}\right)\left(\frac{t}{2a}\right)\left(\frac{\partial f}{\partial x'}\right)^2\left(\frac{\partial^2 f}{\partial x'^2}\right)$$

$$-\left(\frac{w_0}{a}\right)^3\left(\frac{t}{2a}\right)\left(\frac{\partial^2 f}{\partial \theta^2}\right) + 2\left(\frac{w_0}{a}\right)^2\left(\frac{t}{2a}\right)\frac{\partial^2 f}{\partial \theta^2} f$$

$$-\nu\left(\frac{w_0}{a}\right)^3\left(\frac{a}{L}\right)\left(\frac{t}{2a}\right)\left(\frac{\partial f}{\partial x'}\right)^2\left(\frac{\partial^2 f}{\partial \theta^2}\right) - \nu\left(\frac{w_0}{a}\right)^3\left(\frac{a}{L}\right)^3\left(\frac{t}{2a}\right)\left(\frac{\partial^2 f}{\partial x'^2}\right)\left(\frac{\partial f}{\partial \theta}\right)^2$$

$$+2\nu\left(\frac{w_0}{a}\right)^2\left(\frac{a}{L}\right)\left(\frac{t}{2a}\right) f\left(\frac{\partial^2 f}{\partial x'^2}\right) - 2(1-\nu)\left(\frac{w_0}{a}\right)^3\left(\frac{a}{L}\right)^2\left(\frac{t}{2a}\right)\left(\frac{\partial^2 f}{\partial x'\partial \theta}\right)\left(\frac{\partial f}{\partial x'}\right)\left(\frac{\partial f}{\partial \theta}\right),$$

$$\bar{\beta}(x',\theta) = \left(\frac{t}{2}\right)^2\beta_e(x',\theta) = \left(\frac{w_0}{a}\right)^2\left(\frac{a}{L}\right)^4\left(\frac{t}{2a}\right)\left(\frac{\partial^2 f}{\partial x'^2}\right)^2$$

$$+2\nu\left(\frac{w_0}{a}\right)^2\left(\frac{t}{2a}\right)^2\left(\frac{a}{L}\right)^2\left(\frac{\partial^2 f}{\partial x'^2}\right)\left(\frac{\partial^2 f}{\partial \theta^2}\right) + \left(\frac{w_0}{a}\right)^2\left(\frac{t}{2a}\right)^2\left(\frac{\partial^2 f}{\partial \theta^2}\right)^2$$

$$+2(1-\nu)\left(\frac{w_0}{a}\right)^2\left(\frac{a}{L}\right)^2\left(\frac{t}{2a}\right)^2\left(\frac{\partial^2 f}{\partial x'\partial \theta}\right)^2. \qquad [22]$$

It may be shown that Equation [21] reduces to Equation [11] for $\nu = 0.5$. Equation [21] can be further rewritten as

$$\bar{V} = \frac{\sqrt{3}\,V}{\lambda E e_s t a L} = \frac{\sqrt{3}\,(1-\lambda)}{2\lambda e_s (1-\nu^2)}\bar{I}_1 + \bar{V}_1 - \sqrt{3}\,\pi e_s - \underline{\sum_{i=1}^{L} \frac{\sqrt{3}}{2} e_s \frac{A_i}{at}} \qquad [23]$$

where

$$\begin{aligned}\bar{I}_1 = &\int_0^1\int_0^{2\pi} \bar{\alpha}\, dx'\,d\theta + \frac{1}{3}\int_0^1\int_0^{2\pi} \bar{\beta}\, dx'\,d\theta \\ &+ \underline{\sum_{i=1}^{N}\int_0^1 (1-\nu^2)\left[\frac{1}{4}\left(\frac{w_o}{a}\right)^4\left(\frac{a}{L}\right)^2\left(\frac{\partial f}{\partial x'}\right)^4 \frac{A_i}{at} + \left(\frac{w_o}{a}\right)^2\left(\frac{a}{L}\right)^2\left(\frac{\partial^2 f}{\partial x'^2}\right)\frac{I_i}{atL^2}\right] dx'}\end{aligned} \qquad [24]$$

$$\bar{V}_1 = \frac{\sqrt{3}\,V_1}{\lambda E e_s t a L} = \int_0^1\int_0^{2\pi} \Delta\, dx'\,d\theta + \underline{\sum_{i=1}^{N}\int\left[\frac{\sqrt{3}}{2}\left(\frac{w_o}{a}\right)^2\left(\frac{a}{L}\right)^2\left(\frac{\partial f}{\partial x'}\right)^2\frac{A_i}{at}\right] dx'} \qquad [25]$$

and Δ is the underlined portion of Equation [21]. For buckling the spatial function f becomes

$$\begin{aligned} f(x',\theta) &= \sin \pi x'\, e^{-k\theta} \cos n\theta \,, && 0 < \theta < \pi\,, \\ f(x',\theta) &= \sin \pi x'\, e^{-k(2\pi-\theta)} \cos n(2\pi-\theta)\,, && \pi < \theta < 2\pi\,, \end{aligned} \qquad [26]$$

where n is given by Reynolds (20) as

$$n = \frac{1.57}{\left(\frac{L}{D}\right)}\sqrt{1.15\,\frac{L}{D}\sqrt{\frac{D}{t}} - 1}\,, \qquad [27]$$

and D is diameter of the shell.

Here n is not a function of the load intensity or the number of stiffeners. For stiffened shells these parameters should be included.

The above results represent a rather complete and realistic first order approach to obtaining the energy absorbed within a shell structure and for estimating damage data of blast loaded stiffened shell structures. As damage criteria such non-dimensional parameters as $\frac{w_o}{a}$, $\frac{a}{L}$, and t/2a can be used for calculation purposes, when the functional form of w expressed as $w_o f(x', \theta)$, is specified. (Note: $x' = x/L$.)

2.2.2 External Energy Imparted to Shell

For short duration pulses an approximate empirical engineering approach to generating the blast load intensity appears useful for predicting shell deformation in those cases where the impulse may be known and the loading less certain.

Consider the energy flux/unit area of a fixed charge weight at a certain stand off distance from the cylinder to be given approximately as in Reference (21) in the form,

$$E_f \sim c \frac{W}{R^2}$$

In the above expression, W is the charge weight, R the stand-off distance, c a constant, and E_f the energy flux. The total energy imparted to the cylindrical shell is $E_t = E_f A(2\pi aL)$

where a is the cylinder radius and L the length. Thus, the total energy available for damage can be expressed as

$$E_t \sim c\frac{W}{R^2}(2\pi a L).$$

Equating the above expression to the potential energy of the shell during deformation as developed in Section 2.2.1 provides a means for estimating the maximum deflection once the solution of Equation [23] is determined.

A slight modification of the above development can be made if some assumption concerning the type of forcing function is made. For example, if an exponential pressure variation is assumed, then, we can write for a peak pressure P_o and decay constant $\bar{a}$; $P(t) = P_o e^{-t/\bar{a}}$. The impulse/unit area can be easily found from, $I = \int_0^\infty P(t)dt$. In addition, if an expression from Reference (16) is introduced,

$$E_f = \frac{1}{\rho_o c_o}\int_0^\infty [P(t)]^2\, dt\text{, where } t = \text{time},$$

then E_f can be expressed as $E_f = P_o^2\bar{a}/2\rho_o c_o$ where ρ_o represents the density of the medium and c_o the velocity of sound in the medium. Once again equating the total energy generated by the explosive process to the energy absorbed during the deformation of the shell, that is, $E_t \sim V$, leads to

$$V = \frac{PI}{\rho_o c_o}(\pi a L), \qquad [27]$$

where V is given in the preceeding development. The above result appears most interesting in that the essence of the P-I (Pressure-Impulse) or so-called iso-damage curve is recognizable in the form of the equation, and graphical displays of this quantity can be readily plotted. An extensive amount of work in this area has been discussed in Reference (16).

2.2.3 Radial Deflection of the Shell

The preceeding discussion relates to the mechanics of establishing the energy stored within the shell during the deformation process and the external energy imparted to the shell generated by an impulse or pressure pulse loading. In order to establish any meaningful damage or failure criterion some statements regarding the form or criteria for establishing the form of the displacement functions are necessary.

As mentioned in Section 2.2.1, the in-plane displacement components are generally neglected since they are considered small relative to the radial displacement coordinate. For determining the latter quantity several approaches are available.

One direct approach for finding w(t) when w(A) and the applied external pressure loading are known is to use Hamilton's Principle for dynamic systems. Recall that this Principle can be written as

$$\delta \int_{t_1}^{t_2} (T - U)\, dt = 0 , \quad \text{for time } t, \qquad [28]$$

with U = V - W, where V represents the potential energy and W the work done by the external forces. The Kinetic energy T can be written as

$$T = \frac{1}{2} \int_A \mu(A)\, \dot{w}^2\, dA , \qquad [29]$$

where μ(A) represents the mass/unit-area of the structure, dA the element of surface area of the structure, and $\dot{w} = \dot{w}_o(t) f(A)$ represents the radial deflection in terms of time and spatial dependency. The corresponding quantity U represents the difference between the potential energy and the work done by the external forces in the (u-v-w) directions. The quantity V can be further expanded in terms of a power series of the form,

$$V = \bar{A} + \bar{B} w_o + \bar{C} w_o^2 + \bar{D} w_o^3 + \cdots \qquad [30]$$

and the work done by the external forces as,

$$\int P(A,t) f(A)\, dA , \qquad [31]$$

with P(A,t) representing the time varying pressure applied to the external surface of the structure. Substituting the above in Hamilton's equation results in an equation of the Euler form, that is, we can recast Hamilton's Principle as a

problem in the Calculus of Variations of the form

$$I' = \int_a^b F(x, y, y')\,dx, \qquad [32]$$

and obtain Euler's equation,

$$\frac{dF}{dy} - \frac{d}{dx}\left(\frac{\partial F}{\partial y}\right) = 0. \qquad [33]$$

In the present example, $y' = \dot{w}_o$, $x = t$, and $y = w_o(t)$. Upon substitution in the above Euler's equation results in the following nonlinear differential equation for w_o,

$$\ddot{w}_o \int \mu(A) f^2(A)\,dA + (\bar{B} + 2\bar{C} w_o + 3\bar{D} w_o^2 + \cdots) = \int P(A,t)\, f(A)\, dA. \qquad [34]$$

with initial conditions, $w_o(0) = 0$, $\dot{w}_o(0) = 0$, so long as the radial deflection continuously increases without unloading taking place.

As an alternative to solving the above equation the deflection can be considered to be of the form $w = w_o f(x', \theta)$ in the post impact range with $x' = x/L$ and L being the shell length. Then for a collapse type behavior of a shell loaded laterally on the side facing due to a blast load we can write,

$$w(x', \theta) = a \cos\theta \sqrt{a^2 - \left(\frac{D_o}{2}\right)^2 (1 - 2x')^2}, \quad 0 < x' < \frac{L}{2};$$

$$w(x', \theta) = a \cos\theta \sqrt{a^2 - \left(\frac{D_o}{2}\right)^2 (1 + 2x')^2}, \quad -\frac{L}{2} < x' < 0, \qquad [35]^*$$

*D_o shown in Figure 2.

while correspondingly for circumferential buckling the pattern is,

$$w(x', \theta) = w_o \sin \pi x' e^{-k\theta} \cos n\theta \qquad , \; 0 < \theta < \pi,$$
$$w(x', \theta) = w_o \sin \pi x' e^{-k(2\pi - \theta)} \cos n(2\pi - \theta) \; , \; \pi < \theta < 2\pi. \qquad [36]$$

The above functional forms for w can then be substituted into the energy expression for the deforming shell, that is, V and equated to the external energy in order to determine w_o as an explicit function of V.

2.3 Numerical Example

In order to demonstrate the theoretical developments presented, calculations for three different L/D (Length/Diameter) ratios (1, 2, 4) and varying D/t (Diameter/thickness) ratios between 100 to 1200, for each L/D, have been made. The two specific buckling energies $\overline{V}_1, \overline{I}_1$ as defined in the text of this report have been calculated for both the unstiffened and stiffened shells and are presented in the accompanying Tables III - V. Each of these tables represents data generated for eight stiffeners. The influence of increasing the number of stiffeners on the specific buckling energy within the shell is included in Table VI. The last case of Table VI, with 105 stiffeners, represents the maximum packing density of stiffeners which could be suitably retained within the outer shell geometry and was obtained by taking the width of the stiffeners used in

TABLE III. PARAMETER STUDY FOR GREENSPON THEORY
WITH STIFFENERS L/D = 1.0

L/D= 0.10000E 01
D/T= 0.10000E 03
K= 0.25000E 00
N= 0.50000E 01
NU= 0.50000E 00
AREA/A/T= 0.47619E 00
ZBAR/A/T= 0.31746E-01
NUMBER OF STRINGERS= 8

W0/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.44925E-01	0.34553E-03	0.12789E-03	0.20727E-05
0.25000E-01	0.89251E-01	0.10394E-02	0.52099E-03	0.87507E-05
0.37500E-01	0.13433E 00	0.20816E-02	0.12120E-02	0.21196E-04
0.50000E-01	0.18336E 00	0.34722E-02	0.22582E-02	0.41203E-04
0.62500E-01	0.23776E 00	0.52111E-02	0.37416E-02	0.71191E-04
0.75000E-01	0.29759E 00	0.72983E-02	0.57690E-02	0.11421E-03
0.87500E-01	0.36254E 00	0.97339E-02	0.84716E-02	0.17396E-03
0.10000E 00	0.43247E 00	0.12518E-01	0.12005E-01	0.25473E-03
0.11250E 00	0.50740E 00	0.15650E-01	0.16551E-01	0.36147E-03
0.12500E 00	0.58740E 00	0.19131E-01	0.22314E-01	0.49975E-03
0.15000E 00	0.76344E 00	0.27137E-01	0.38437E-01	0.89639E-03
0.17500E 00	0.96283E 00	0.36537E-01	0.62509E-01	0.15018E-02
0.20000E 00	0.11874E 01	0.47330E-01	0.97061E-01	0.23833E-02
0.22500E 00	0.14384E 01	0.59516E-01	0.14502E 00	0.36182E-02
0.25000E 00	0.17160E 01	0.73096E-01	0.20970E 00	0.52938E-02
0.27500E 00	0.20203E 01	0.88069E-01	0.29483E 00	0.75077E-02
0.30000E 00	0.23517E 01	0.10444E 00	0.40451E 00	0.10368E-01
0.32500E 00	0.27104E 01	0.12220E 00	0.54323E 00	0.13991E-01
0.35000E 00	0.30966E 01	0.14135E 00	0.71592E 00	0.18505E-01
0.37500E 00	0.35104E 01	0.16190E 00	0.92785E 00	0.24049E-01
0.40000E 00	0.39517E 01	0.18384E 00	0.11847E 01	0.30770E-01
0.42500E 00	0.44204E 01	0.20717E 00	0.14926E 01	0.38825E-01
0.45000E 00	0.49165E 01	0.23190E 00	0.18580E 01	0.48383E-01
0.47500E 00	0.54399E 01	0.25802E 00	0.22877E 01	0.59623E-01
0.50000E 00	0.59905E 01	0.28553E 00	0.27891E 01	0.72732E-01
0.52500E 00	0.65684E 01	0.31444E 00	0.33698E 01	0.87908E-01
0.55000E 00	0.71735E 01	0.34474E 00	0.40378E 01	0.10536E 00
0.57500E 00	0.78057E 01	0.37643E 00	0.48016E 01	0.12531E 00
0.60000E 00	0.84650E 01	0.40952E 00	0.56701E 01	0.14798E 00
0.62500E 00	0.91514E 01	0.44400E 00	0.66524E 01	0.17361E 00
0.65000E 00	0.98649E 01	0.47987E 00	0.77583E 01	0.20245E 00
0.67500E 00	0.10605E 02	0.51714E 00	0.89978E 01	0.23476E 00
0.70000E 00	0.11373E 02	0.55580E 00	0.10381E 02	0.27081E 00
0.72500E 00	0.12168E 02	0.59585E 00	0.11919E 02	0.31087E 00
0.75000E 00	0.12990E 02	0.63730E 00	0.13624E 02	0.35524E 00
0.77500E 00	0.13839E 02	0.68014E 00	0.15505E 02	0.40422E 00
0.80000E 00	0.14715E 02	0.72438E 00	0.17577E 02	0.45811E 00

TABLE III. (Continued)

L/D= 0.10000E 01
D/T= 0.20000E 03
K= 0.25000E 00
N= 0.60000E 01
NU= 0.50000E 00
AREA/A/T= 0.23810E 00
ZBAR/A/T= 0.15873E-01
NUMBER OF STRINGERS= 8

W0/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.44880E-01	0.11137E-03	0.12696E-03	0.26448E-06
0.25000E-01	0.91925E-01	0.39125E-03	0.52887E-03	0.12596E-05
0.37500E-01	0.14286E 00	0.83964E-03	0.12767E-02	0.35492E-05
0.50000E-01	0.19888E 00	0.14565E-02	0.24940E-02	0.80457E-05
0.62500E-01	0.26035E 00	0.22419E-02	0.43567E-02	0.16010E-04
0.75000E-01	0.32864E 00	0.31959E-02	0.70935E-02	0.29052E-04
0.87500E-01	0.40559E 00	0.43183E-02	0.10985E-01	0.49128E-04
0.10000E 00	0.49197E 00	0.56092E-02	0.16366E-01	0.78547E-04
0.11250E 00	0.58740E 00	0.70687E-02	0.23622E-01	0.11996E-03
0.12500E 00	0.69147E 00	0.86967E-02	0.33191E-01	0.17638E-03
0.15000E 00	0.92509E 00	0.12458E-01	0.61289E-01	0.34797E-03
0.17500E 00	0.11927E 01	0.16894E-01	0.10522E 00	0.62431E-03
0.20000E 00	0.14950E 01	0.22003E-01	0.17038E 00	0.10420E-02
0.22500E 00	0.18333E 01	0.27787E-01	0.26302E 00	0.16431E-02
0.25000E 00	0.22085E 01	0.34244E-01	0.39022E 00	0.24755E-02
0.27500E 00	0.26209E 01	0.41376E-01	0.55990E 00	0.35924E-02
0.30000E 00	0.30705E 01	0.49182E-01	0.78082E 00	0.50526E-02
0.32500E 00	0.35570E 01	0.57661E-01	0.10626E 01	0.69207E-02
0.35000E 00	0.40805E 01	0.66815E-01	0.14157E 01	0.92667E-02
0.37500E 00	0.46413E 01	0.76643E-01	0.18513E 01	0.12166E-01
0.40000E 00	0.52397E 01	0.87145E-01	0.23816E 01	0.15700E-01
0.42500E 00	0.58759E 01	0.98321E-01	0.30197E 01	0.19956E-01
0.45000E 00	0.65499E 01	0.11017E 00	0.37792E 01	0.25025E-01
0.47500E 00	0.72619E 01	0.12269E 00	0.46748E 01	0.31006E-01
0.50000E 00	0.80118E 01	0.13589E 00	0.57220E 01	0.38002E-01
0.52500E 00	0.87994E 01	0.14977E 00	0.69372E 01	0.46123E-01
0.55000E 00	0.96248E 01	0.16431E 00	0.83375E 01	0.55482E-01
0.57500E 00	0.10488E 02	0.17953E 00	0.99409E 01	0.66201E-01
0.60000E 00	0.11388E 02	0.19543E 00	0.11766E 02	0.78404E-01
0.62500E 00	0.12327E 02	0.21199E 00	0.13833E 02	0.92223E-01
0.65000E 00	0.13302E 02	0.22924E 00	0.16163E 02	0.10780E 00
0.67500E 00	0.14316E 02	0.24715E 00	0.18775E 02	0.12526E 00
0.70000E 00	0.15367E 02	0.26574E 00	0.21694E 02	0.14478E 00
0.72500E 00	0.16455E 02	0.28501E 00	0.24941E 02	0.16649E 00
0.75000E 00	0.17582E 02	0.30495E 00	0.28541E 02	0.19055E 00
0.77500E 00	0.18746E 02	0.32556E 00	0.32519E 02	0.21714E 00
0.80000E 00	0.19948E 02	0.34684E 00	0.36900E 02	0.24642E 00

TABLE III. (Continued)

L/D= 0.10000E 01
D/T= 0.40000E 03
K= 0.25000E 00
N= 0.70000E 01
NU= 0.50000E 00
AREA/A/T= 0.11905E 00
ZBAR/A/T= 0.79365E-02
NUMBER OF STRINGERS= 8

W0/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.44600E-01	0.10276E-03	0.12579E-03	0.42179E-07
0.25000E-01	0.91823E-01	0.29261E-03	0.53808E-03	0.26429E-06
0.37500E-01	0.14278E 00	0.56954E-03	0.13590E-02	0.92783E-06
0.50000E-01	0.20313E 00	0.93356E-03	0.28038E-02	0.24517E-05
0.62500E-01	0.27567E 00	0.13847E-02	0.51808E-02	0.54125E-05
0.75000E-01	0.35933E 00	0.19229E-02	0.88914E-02	0.10544E-04
0.87500E-01	0.45546E 00	0.25481E-02	0.14430E-01	0.18738E-04
0.10000E 00	0.56423E 00	0.32605E-02	0.22384E-01	0.31043E-04
0.11250E 00	0.68511E 00	0.40599E-02	0.33434E-01	0.48665E-04
0.12500E 00	0.81797E 00	0.49465E-02	0.48354E-01	0.72969E-04
0.15000E 00	0.11203E 01	0.69808E-02	0.93364E-01	0.14786E-03
0.17500E 00	0.14723E 01	0.93635E-02	0.16546E 00	0.26979E-03
0.20000E 00	0.18734E 01	0.12095E-01	0.27419E 00	0.45533E-03
0.22500E 00	0.23235E 01	0.15174E-01	0.43058E 00	0.72357E-03
0.25000E 00	0.28228E 01	0.18602E-01	0.64714E 00	0.10962E-02
0.27500E 00	0.33722E 01	0.22378E-01	0.93789E 00	0.15972E-02
0.30000E 00	0.39726E 01	0.26502E-01	0.13183E 01	0.22534E-02
0.32500E 00	0.46238E 01	0.30975E-01	0.18054E 01	0.30939E-02
0.35000E 00	0.53256E 01	0.35796E-01	0.24177E 01	0.41504E-02
0.37500E 00	0.60778E 01	0.40965E-01	0.31750E 01	0.54571E-02
0.40000E 00	0.68804E 01	0.46483E-01	0.40989E 01	0.70508E-02
0.42500E 00	0.77333E 01	0.52349E-01	0.52123E 01	0.89708E-02
0.45000E 00	0.86365E 01	0.58564E-01	0.65396E 01	0.11259E-01
0.47500E 00	0.95900E 01	0.65126E-01	0.81068E 01	0.13959E-01
0.50000E 00	0.10594E 02	0.72038E-01	0.99412E 01	0.17118E-01
0.52500E 00	0.11648E 02	0.79297E-01	0.12072E 02	0.20786E-01
0.55000E 00	0.12753E 02	0.86905E-01	0.14529E 02	0.25014E-01
0.57500E 00	0.13908E 02	0.94861E-01	0.17345E 02	0.29857E-01
0.60000E 00	0.15114E 02	0.10317E 00	0.20552E 02	0.35372E-01
0.62500E 00	0.16371E 02	0.11182E 00	0.24186E 02	0.41617E-01
0.65000E 00	0.17678E 02	0.12082E 00	0.28283E 02	0.48656E-01
0.67500E 00	0.19036E 02	0.13017E 00	0.32881E 02	0.56551E-01
0.70000E 00	0.20445E 02	0.13987E 00	0.38019E 02	0.65372E-01
0.72500E 00	0.21905E 02	0.14991E 00	0.43738E 02	0.75186E-01
0.75000E 00	0.23415E 02	0.16031E 00	0.50080E 02	0.86066E-01
0.77500E 00	0.24977E 02	0.17105E 00	0.57089E 02	0.98086E-01
0.80000E 00	0.26589E 02	0.18214E 00	0.64811E 02	0.11132E 00

TABLE III. (Continued)

L/D= 0.10000E 01
D/T= 0.60000E 03
K= 0.25000E 00
N= 0.80000E 01
NU= 0.50000E 00
AREA/A/T= 0.79365E-01
ZBAR/A/T= 0.52910E-02
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.44422E-01	0.21293E-03	0.12983E-03	0.30875E-07
0.25000E-01	0.95600E-01	0.53413E-03	0.60137E-03	0.24554E-06
0.37500E-01	0.15935E 00	0.96360E-03	0.16623E-02	0.97996E-06
0.50000E-01	0.23556E 00	0.15013E-02	0.37263E-02	0.27740E-05
0.62500E-01	0.32555E 00	0.21473E-02	0.73734E-02	0.63713E-05
0.75000E-01	0.43079E 00	0.29016E-02	0.13349E-01	0.12719E-04
0.87500E-01	0.55075E 00	0.37642E-02	0.22567E-01	0.22970E-04
0.10000E 00	0.68617E 00	0.47350E-02	0.36103E-01	0.38478E-04
0.11250E 00	0.83750E 00	0.58141E-02	0.55203E-01	0.60803E-04
0.12500E 00	0.10044E 01	0.70015E-02	0.81278E-01	0.91709E-04
0.15000E 00	0.13848E 01	0.97010E-02	0.16082E 00	0.18733E-03
0.17500E 00	0.18287E 01	0.12834E-01	0.28934E 00	0.34353E-03
0.20000E 00	0.23385E 01	0.16399E-01	0.48410E 00	0.58174E-03
0.22500E 00	0.29157E 01	0.20398E-01	0.76501E 00	0.92668E-03
0.25000E 00	0.35594E 01	0.24830E-01	0.11547E 01	0.14063E-02
0.27500E 00	0.42690E 01	0.29695E-01	0.16783E 01	0.20519E-02
0.30000E 00	0.50443E 01	0.34993E-01	0.23638E 01	0.28978E-02
0.32500E 00	0.58852E 01	0.40724E-01	0.32417E 01	0.39820E-02
0.35000E 00	0.67917E 01	0.46888E-01	0.43453E 01	0.53453E-02
0.37500E 00	0.77637E 01	0.53486E-01	0.57103E 01	0.70321E-02
0.40000E 00	0.88014E 01	0.60516E-01	0.73754E 01	0.90898E-02
0.42500E 00	0.99046E 01	0.67980E-01	0.93817E 01	0.11569E-01
0.45000E 00	0.11074E 02	0.75876E-01	0.11773E 02	0.14525E-01
0.47500E 00	0.12308E 02	0.84206E-01	0.14596E 02	0.18014E-01
0.50000E 00	0.13609E 02	0.92969E-01	0.17900E 02	0.22096E-01
0.52500E 00	0.14975E 02	0.10216E 00	0.21736E 02	0.26836E-01
0.55000E 00	0.16407E 02	0.11179E 00	0.26159E 02	0.32301E-01
0.57500E 00	0.17906E 02	0.12186E 00	0.31226E 02	0.38561E-01
0.60000E 00	0.19470E 02	0.13235E 00	0.36997E 02	0.45689E-01
0.62500E 00	0.21101E 02	0.14328E 00	0.43535E 02	0.53764E-01
0.65000E 00	0.22798E 02	0.15464E 00	0.50904E 02	0.62864E-01
0.67500E 00	0.24562E 02	0.16643E 00	0.59172E 02	0.73073E-01
0.70000E 00	0.26392E 02	0.17866E 00	0.68410E 02	0.84479E-01
0.72500E 00	0.28290E 02	0.19132E 00	0.78691E 02	0.97170E-01
0.75000E 00	0.30254E 02	0.20442E 00	0.90090E 02	0.11124E 00
0.77500E 00	0.32286E 02	0.21794E 00	0.10269E 03	0.12679E 00
0.80000E 00	0.34385E 02	0.23190E 00	0.11656E 03	0.14391E 00

TABLE III. (Continued)

L/D= 0.10000E 01
D/T= 0.80000E 03
K= 0.25000E 00
N= 0.90000E 01
NU= 0.50000E 00
AREA/A/T= 0.59524E-01
ZBAR/A/T= 0.39683E-02
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43392E-01	0.36576E-04	0.12732E-03	0.82592E-08
0.25000E-01	0.98584E-01	0.11669E-03	0.63108E-03	0.76617E-07
0.37500E-01	0.17000E 00	0.24036E-03	0.19047E-02	0.32950E-06
0.50000E-01	0.25823E 00	0.40756E-03	0.46226E-02	0.97009E-06
0.62500E-01	0.36366E 00	0.61831E-03	0.97399E-02	0.22803E-05
0.75000E-01	0.48807E 00	0.87260E-03	0.18493E-01	0.46208E-05
0.87500E-01	0.63344E 00	0.11704E-02	0.32398E-01	0.84309E-05
0.10000E 00	0.79958E 00	0.15118E-02	0.53255E-01	0.14229E-04
0.11250E 00	0.98761E 00	0.18967E-02	0.83141E-01	0.22612E-04
0.12500E 00	0.11977E 01	0.23252E-02	0.12442E 00	0.34255E-04
0.15000E 00	0.16821E 01	0.33128E-02	0.25198E 00	0.70418E-04
0.17500E 00	0.22511E 01	0.44745E-02	0.46044E 00	0.12970E-03
0.20000E 00	0.29043E 01	0.58104E-02	0.77879E 00	0.22034E-03
0.22500E 00	0.36418E 01	0.73205E-02	0.12405E 01	0.35183E-03
0.25000E 00	0.44638E 01	0.90047E-02	0.18836E 01	0.53495E-03
0.27500E 00	0.53711E 01	0.10863E-01	0.27505E 01	0.78170E-03
0.30000E 00	0.63638E 01	0.12896E-01	0.38883E 01	0.11054E-02
0.32500E 00	0.74415E 01	0.15102E-01	0.53483E 01	0.15205E-02
0.35000E 00	0.86042E 01	0.17483E-01	0.71865E 01	0.20429E-02
0.37500E 00	0.98517E 01	0.20039E-01	0.94634E 01	0.26896E-02
0.40000E 00	0.11184E 02	0.22768E-01	0.12244E 02	0.34789E-02
0.42500E 00	0.12601E 02	0.25671E-01	0.15598E 02	0.44304E-02
0.45000E 00	0.14103E 02	0.28749E-01	0.19598E 02	0.55650E-02
0.47500E 00	0.15690E 02	0.32001E-01	0.24324E 02	0.69047E-02
0.50000E 00	0.17362E 02	0.35427E-01	0.29859E 02	0.84730E-02
0.52500E 00	0.19119E 02	0.39027E-01	0.36289E 02	0.10294E-01
0.55000E 00	0.20961E 02	0.42801E-01	0.43707E 02	0.12395E-01
0.57500E 00	0.22887E 02	0.46750E-01	0.52209E 02	0.14801E-01
0.60000E 00	0.24899E 02	0.50872E-01	0.61896E 02	0.17542E-01
0.62500E 00	0.26995E 02	0.55169E-01	0.72874E 02	0.20648E-01
0.65000E 00	0.29176E 02	0.59640E-01	0.85252E 02	0.24148E-01
0.67500E 00	0.31443E 02	0.64285E-01	0.99144E 02	0.28076E-01
0.70000E 00	0.33794E 02	0.69105E-01	0.11467E 03	0.32464E-01
0.72500E 00	0.36231E 02	0.74098E-01	0.13195E 03	0.37348E-01
0.75000E 00	0.38753E 02	0.79266E-01	0.15112E 03	0.42763E-01
0.77500E 00	0.41359E 02	0.84608E-01	0.17231E 03	0.48747E-01
0.80000E 00	0.44051E 02	0.90124E-01	0.19565E 03	0.55338E-01

TABLE III. (Continued)

L/D= 0.10C00E 01
D/T= 0.10000E 04
K= 0.2500CE 00
N= 0.5000CE 01
NU= 0.500C0E 00
AREA/A/T= 0.47619E-01
ZBAR/A/T= 0.31746E-02
NUMBER OF STRINGERS= 8

WC/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43241E-01	0.26892E-04	0.12716E-03	0.53083E-08
0.25000E-01	0.98472E-01	0.88619E-04	0.63046E-03	0.55424E-07
0.37500E-01	0.16995E 00	0.18518E-03	0.19033E-02	0.24888E-06
0.50000E-01	0.25817E 00	0.31657E-03	0.46201E-02	0.74721E-06
0.62500E-01	0.36360E 00	0.48280E-03	0.97360E-02	0.17749E-05
0.75000E-01	0.48796E 00	0.68387E-03	0.18487E-01	0.36196E-05
0.87500E-01	0.63335E 00	0.91977E-03	0.32391E-01	0.66316E-05
0.10000E 00	0.79942E 00	0.11905E-02	0.53245E-01	0.11225E-04
0.11250E 00	0.98748E 00	0.14961E-02	0.83128E-01	0.17875E-04
0.12500E 00	0.11976E 01	0.18365E-02	0.12440E 00	0.27122E-04
0.15000E 00	0.16820E 01	0.26218E-02	0.25196E 00	0.55881E-04
0.17500E 00	0.22510E 01	0.35464E-02	0.46041E 00	0.10308E-03
0.20000E 00	0.29042E 01	0.46104E-02	0.77875E 00	0.17529E-03
0.22500E 00	0.36417E 01	0.58137E-02	0.12405E 01	0.28012E-03
0.25000E 00	0.44636E 01	0.71564E-02	0.18835E 01	0.42616E-03
0.27500E 00	0.53710E 01	0.86384E-02	0.27505E 01	0.62302E-03
0.30000E 00	0.63637E 01	0.10260E-01	0.38882E 01	0.88131E-03
0.32500E 00	0.74414E 01	0.12020E-01	0.53481E 01	0.12127E-02
0.35000E 00	0.86041E 01	0.13920E-01	0.71864E 01	0.16297E-02
0.37500E 00	0.98516E 01	0.15960E-01	0.94632E 01	0.21461E-02
0.40000E 00	0.11184E 02	0.18138E-01	0.12244E 02	0.27764E-02
0.42500E 00	0.12601E 02	0.20456E-01	0.15597E 02	0.35364E-02
0.45000E 00	0.14103E 02	0.22914E-01	0.19598E 02	0.44427E-02
0.47500E 00	0.15690E 02	0.25511E-01	0.24324E 02	0.55129E-02
0.50000E 00	0.17362E 02	0.28247E-01	0.29858E 02	0.67658E-02
0.52500E 00	0.19119E 02	0.31122E-01	0.36289E 02	0.82210E-02
0.55000E 00	0.20960E 02	0.34137E-01	0.43707E 02	0.98993E-02
0.57500E 00	0.22887E 02	0.37291E-01	0.52209E 02	0.11822E-01
0.60000E 00	0.24898E 02	0.40584E-01	0.61896E 02	0.14013E-01
0.62500E 00	0.26995E 02	0.44017E-01	0.72873E 02	0.16494E-01
0.65000E 00	0.29176E 02	0.47589E-01	0.85251E 02	0.19292E-01
0.67500E 00	0.31443E 02	0.51300E-01	0.99144E 02	0.22431E-01
0.70000E 00	0.33794E 02	0.55151E-01	0.11467E 03	0.25938E-01
0.72500E 00	0.36231E 02	0.59141E-01	0.13195E 03	0.29842E-01
0.75000E 00	0.38752E 02	0.63270E-01	0.15112E 03	0.34170E-01
0.77500E 00	0.41359E 02	0.67539E-01	0.17231E 03	0.38953E-01
0.80000E 00	0.44051E 02	0.71947E-01	0.19565E 03	0.44222E-01

TABLE III. (Concluded)

L/D= 0.10000E 01
D/T= 0.12000E 04
K= 0.2500CE 00
N= 0.1000CE 02
NU= 0.50000E 00
AREA/A/T= 0.39683E-01
ZBAR/A/T= 0.26455E-02
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.40188E-01	0.14796E-04	0.13085E-03	0.37361E-08
0.25000E-01	0.10380E 00	0.57676E-04	0.73056E-03	0.44749E-07
0.37500E-01	0.19490E 00	0.12864E-03	0.24465E-02	0.21131E-06
0.50000E-01	0.31263E 00	0.22769E-03	0.63748E-02	0.64977E-06
0.62500E-01	0.45698E 00	0.35483E-03	0.14060E-01	0.15646E-05
0.75000E-01	0.62795E 00	0.51005E-03	0.27497E-01	0.32183E-05
0.87500E-01	0.82555E 00	0.69336E-03	0.49127E-01	0.59314E-05
0.10000E 00	0.10498E 01	0.90475E-03	0.81842E-01	0.10083E-04
0.11250E 00	0.13007E 01	0.11442E-02	0.12898E 00	0.16109E-04
0.12500E 00	0.15783E 01	0.14118E-02	0.19434E 00	0.24505E-04
0.15000E 00	0.22134E 01	0.20312E-02	0.39709E 00	0.50677E-04
0.17500E 00	0.29553E 01	0.27629E-02	0.72938E 00	0.93719E-04
0.20000E 00	0.38040E 01	0.36069E-02	0.12377E 01	0.15968E-03
0.22500E 00	0.47596E 01	0.45633E-02	0.19756E 01	0.25554E-03
0.25000E 00	0.58221E 01	0.56321E-02	0.30041E 01	0.38921E-03
0.27500E 00	0.69915E 01	0.68132E-02	0.43910E 01	0.56953E-03
0.30000E 00	0.82680E 01	0.81066E-02	0.62117E 01	0.80626E-03
0.32500E 00	0.96514E 01	0.95123E-02	0.85483E 01	0.11101E-02
0.35000E 00	0.11142E 02	0.11030E-01	0.11491E 02	0.14927E-02
0.37500E 00	0.12739E 02	0.12661E-01	0.15135E 02	0.19665E-02
0.40000E 00	0.14444E 02	0.14404E-01	0.19586E 02	0.25452E-02
0.42500E 00	0.16256E 02	0.16259E-01	0.24954E 02	0.32430E-02
0.45000E 00	0.18175E 02	0.18226E-01	0.31358E 02	0.40754E-02
0.47500E 00	0.20201E 02	0.20306E-01	0.38923E 02	0.50586E-02
0.50000E 00	0.22334E 02	0.22498E-01	0.47782E 02	0.62098E-02
0.52500E 00	0.24575E 02	0.24803E-01	0.58074E 02	0.75472E-02
0.55000E 00	0.26923E 02	0.27220E-01	0.69947E 02	0.90897E-02
0.57500E 00	0.29378E 02	0.29749E-01	0.83554E 02	0.10857E-01
0.60000E 00	0.31940E 02	0.32390E-01	0.99058E 02	0.12871E-01
0.62500E 00	0.34609E 02	0.35144E-01	0.11663E 03	0.15153E-01
0.65000E 00	0.37386E 02	0.38010E-01	0.13643E 03	0.17726E-01
0.67500E 00	0.40270E 02	0.40989E-01	0.15867E 03	0.20613E-01
0.70000E 00	0.43262E 02	0.44080E-01	0.18351E 03	0.23839E-01
0.72500E 00	0.46360E 02	0.47283E-01	0.21117E 03	0.27430E-01
0.75000E 00	0.49566E 02	0.50598E-01	0.24184E 03	0.31412E-01
0.77500E 00	0.52880E 02	0.54026E-01	0.27573E 03	0.35812E-01
0.80000E 00	0.56300E 02	0.57566E-01	0.31308E 03	0.40659E-01

TABLE IV. PARAMETER STUDY FOR GREENSPON THEORY WITH STIFFENERS L/D = 2.0.

L/D= 0.20000E 01
D/T= 0.10000E 03
K= 0.25000E 00
N= 0.40000E 01
NU= 0.50000E 00
AREA/A/T= 0.47615E 00
ZBAR/A/T= 0.15873E-01
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43910E-01	0.94890E-04	0.12549E-03	0.24797E-06
0.25000E-01	0.88869E-01	0.35219E-03	0.50517E-03	0.11485E-05
0.37500E-01	0.13467E 00	0.77189E-03	0.11514E-02	0.31658E-05
0.50000E-01	0.18138E 00	0.13540E-02	0.20867E-02	0.70700E-05
0.62500E-01	0.22933E 00	0.20985E-02	0.33438E-02	0.13937E-04
0.75000E-01	0.27943E 00	0.30054E-02	0.49653E-02	0.25149E-04
0.87500E-01	0.33215E 00	0.40748E-02	0.70041E-02	0.42392E-04
0.10000E 00	0.38781E 00	0.53065E-02	0.95233E-02	0.67661E-04
0.11250E 00	0.44685E 00	0.67006E-02	0.12596E-01	0.10325E-03
0.12500E 00	0.50903E 00	0.82572E-02	0.16305E-01	0.15178E-03
0.15000E 00	0.64223E 00	0.11858E-01	0.26018E-01	0.29956E-03
0.17500E 00	0.78698E 00	0.16107E-01	0.39530E-01	0.53797E-03
0.20000E 00	0.94340E 00	0.21007E-01	0.57872E-01	0.89885E-03
0.22500E 00	0.11118E 01	0.26556E-01	0.82235E-01	0.14189E-02
0.25000E 00	0.12929E 01	0.32755E-01	0.11398E 00	0.21399E-02
0.27500E 00	0.14879E 01	0.39604E-01	0.15461E 00	0.31082E-02
0.30000E 00	0.16979E 01	0.47102E-01	0.20581E 00	0.43753E-02
0.32500E 00	0.19232E 01	0.55249E-01	0.26943E 00	0.59975E-02
0.35000E 00	0.21640E 01	0.64047E-01	0.34746E 00	0.80361E-02
0.37500E 00	0.24212E 01	0.73494E-01	0.44207E 00	0.10557E-01
0.40000E 00	0.26951E 01	0.83590E-01	0.55559E 00	0.13631E-01
0.42500E 00	0.29861E 01	0.94336E-01	0.69049E 00	0.17335E-01
0.45000E 00	0.32943E 01	0.10573E 00	0.84945E 00	0.21749E-01
0.47500E 00	0.36196E 01	0.11778E 00	0.10353E 01	0.26958E-01
0.50000E 00	0.39616E 01	0.13047E 00	0.12509E 01	0.33054E-01
0.52500E 00	0.43200E 01	0.14382E 00	0.14995E 01	0.40132E-01
0.55000E 00	0.46948E 01	0.15781E 00	0.17844E 01	0.48291E-01
0.57500E 00	0.50857E 01	0.17246E 00	0.21090E 01	0.57638E-01
0.60000E 00	0.54928E 01	0.18775E 00	0.24769E 01	0.68283E-01
0.62500E 00	0.59161E 01	0.20369E 00	0.28920E 01	0.80340E-01
0.65000E 00	0.63555E 01	0.22029E 00	0.33581E 01	0.93930E-01
0.67500E 00	0.68109E 01	0.23753E 00	0.38795E 01	0.10918E 00
0.70000E 00	0.72825E 01	0.25542E 00	0.44603E 01	0.12621E 00
0.72500E 00	0.77700E 01	0.27396E 00	0.51049E 01	0.14517E 00
0.75000E 00	0.82736E 01	0.29315E 00	0.58181E 01	0.16618E 00
0.77500E 00	0.87932E 01	0.31299E 00	0.66045E 01	0.18940E 00
0.80000E 00	0.93289E 01	0.33348E 00	0.74691E 01	0.21498E 00

TABLE IV. (Continued)

L/D= 0.20000E 01
D/T= 0.20000E 03
K= 0.25000E 00
N= 0.40000E 01
NU= 0.50000E 00
AREA/A/T= 0.23810E 00
ZBAR/A/T= 0.79365E-02
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43373E-01	0.44023E-04	0.12464E-03	0.35890E-07
0.25000E-01	0.88638E-01	0.16925E-03	0.50176E-03	0.22094E-06
0.37500E-01	0.13441E 00	0.37568E-03	0.11437E-02	0.78590E-06
0.50000E-01	0.18114E 00	0.66331E-03	0.20731E-02	0.21144E-05
0.62500E-01	0.22889E 00	0.10321E-02	0.33224E-02	0.47431E-05
0.75000E-01	0.27899E 00	0.14822E-02	0.49346E-02	0.93613E-05
0.87500E-01	0.33165E 00	0.20134E-02	0.69623E-02	0.16811E-04
0.10000E 00	0.38722E 00	0.26259E-02	0.94688E-02	0.28089E-04
0.11250E 00	0.44629E 00	0.33195E-02	0.12527E-01	0.44342E-04
0.12500E 00	0.50846E 00	0.40944E-02	0.16220E-01	0.66871E-04
0.15000E 00	0.64162E 00	0.58877E-02	0.25895E-01	0.13673E-03
0.17500E 00	0.78632E 00	0.80058E-02	0.39363E-01	0.25113E-03
0.20000E 00	0.94255E 00	0.10449E-01	0.57653E-01	0.42598E-03
0.22500E 00	0.11108E 01	0.13217E-01	0.81959E-01	0.67965E-03
0.25000E 00	0.12916E 01	0.16309E-01	0.11363E 00	0.10329E-02
0.27500E 00	0.14861E 01	0.19726E-01	0.15420E 00	0.15091E-02
0.30000E 00	0.16959E 01	0.23469E-01	0.20532E 00	0.21338E-02
0.32500E 00	0.19210E 01	0.27536E-01	0.26885E 00	0.29353E-02
0.35000E 00	0.21617E 01	0.31928E-01	0.34679E 00	0.39441E-02
0.37500E 00	0.24181E 01	0.36644E-01	0.44130E 00	0.51932E-02
0.40000E 00	0.26915E 01	0.41686E-01	0.55471E 00	0.67181E-02
0.42500E 00	0.29828E 01	0.47052E-01	0.68951E 00	0.85569E-02
0.45000E 00	0.32915E 01	0.52743E-01	0.84834E 00	0.10750E-01
0.47500E 00	0.36171E 01	0.58759E-01	0.10340E 01	0.13340E-01
0.50000E 00	0.39592E 01	0.65100E-01	0.12495E 01	0.16372E-01
0.52500E 00	0.43177E 01	0.71765E-01	0.14980E 01	0.19894E-01
0.55000E 00	0.46925E 01	0.78755E-01	0.17827E 01	0.23956E-01
0.57500E 00	0.50835E 01	0.86071E-01	0.21072E 01	0.28611E-01
0.60000E 00	0.54907E 01	0.93710E-01	0.24749E 01	0.33913E-01
0.62500E 00	0.59140E 01	0.10168E 00	0.28898E 01	0.39921E-01
0.65000E 00	0.63533E 01	0.10996E 00	0.33558E 01	0.46695E-01
0.67500E 00	0.68088E 01	0.11858E 00	0.38770E 01	0.54295E-01
0.70000E 00	0.72803E 01	0.12752E 00	0.44576E 01	0.62789E-01
0.72500E 00	0.77679E 01	0.13678E 00	0.51021E 01	0.72242E-01
0.75000E 00	0.82715E 01	0.14637E 00	0.58150E 01	0.82725E-01
0.77500E 00	0.87911E 01	0.15628E 00	0.66012E 01	0.94309E-01
0.80000E 00	0.93268E 01	0.16652E 00	0.74656E 01	0.10707E 00

TABLE IV. (Continued)

L/D= 0.20000E 01
D/T= 0.40000E 03
K= 0.25000E 00
N= 0.50000E 01
NU= 0.50000E 00
AREA/A/T= 0.11905E 00
ZBAR/A/T= 0.39683E-02
NUMBER OF STRINGERS= 8

W0/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43855E-01	0.13563E-04	0.12493E-03	0.37452E-08
0.25000E-01	0.88186E-01	0.48898E-04	0.50890E-03	0.35233E-07
0.37500E-01	0.13265E 00	0.10600E-03	0.11837E-02	0.15437E-06
0.50000E-01	0.18085E 00	0.18488E-03	0.22050E-02	0.46044E-06
0.62500E-01	0.23443E 00	0.28553E-03	0.36526E-02	0.10921E-05
0.75000E-01	0.29335E 00	0.40795E-03	0.56303E-02	0.22274E-05
0.87500E-01	0.35709E 00	0.55214E-03	0.82656E-02	0.40836E-05
0.10000E 00	0.42556E 00	0.71811E-03	0.11710E-01	0.69177E-05
0.11250E 00	0.49870E 00	0.90584E-03	0.16140E-01	0.11026E-04
0.12500E 00	0.57650E 00	0.11154E-02	0.21755E-01	0.16743E-04
0.15000E 00	0.74610E 00	0.15997E-02	0.37458E-01	0.34545E-04
0.17500E 00	0.93592E 00	0.21711E-02	0.60896E-01	0.63795E-04
0.20000E 00	0.11510E 01	0.28296E-02	0.94531E-01	0.10859E-03
0.22500E 00	0.13901E 01	0.35752E-02	0.14121E 00	0.17368E-03
0.25000E 00	0.16536E 01	0.44079E-02	0.20415E 00	0.26440E-03
0.27500E 00	0.19420E 01	0.53276E-02	0.28698E 00	0.38676E-03
0.30000E 00	0.22556E 01	0.63345E-02	0.39369E 00	0.54737E-03
0.32500E 00	0.25952E 01	0.74284E-02	0.52866E 00	0.75349E-03
0.35000E 00	0.29610E 01	0.86094E-02	0.69665E 00	0.10130E-02
0.37500E 00	0.33525E 01	0.98775E-02	0.90281E 00	0.13344E-02
0.40000E 00	0.37699E 01	0.11233E-01	0.11527E 01	0.17268E-02
0.42500E 00	0.42134E 01	0.12675E-01	0.14522E 01	0.22001E-02
0.45000E 00	0.46828E 01	0.14204E-01	0.18076E 01	0.27646E-02
0.47500E 00	0.51779E 01	0.15821E-01	0.22256E 01	0.34313E-02
0.50000E 00	0.56985E 01	0.17524E-01	0.27132E 01	0.42119E-02
0.52500E 00	0.62447E 01	0.19315E-01	0.32780E 01	0.51187E-02
0.55000E 00	0.68163E 01	0.21193E-01	0.39278E 01	0.61646E-02
0.57500E 00	0.74133E 01	0.23157E-01	0.46707E 01	0.73632E-02
0.60000E 00	0.80356E 01	0.25209E-01	0.55154E 01	0.87287E-02
0.62500E 00	0.86834E 01	0.27348E-01	0.64708E 01	0.10276E-01
0.65000E 00	0.93565E 01	0.29574E-01	0.75464E 01	0.12020E-01
0.67500E 00	0.10055E 02	0.31887E-01	0.87519E 01	0.13977E-01
0.70000E 00	0.10779E 02	0.34288E-01	0.10097E 02	0.16165E-01
0.72500E 00	0.11528E 02	0.36775E-01	0.11593E 02	0.18599E-01
0.75000E 00	0.12302E 02	0.39349E-01	0.13251E 02	0.21299E-01
0.77500E 00	0.13102E 02	0.42011E-01	0.15081E 02	0.24282E-01
0.80000E 00	0.13927E 02	0.44759E-01	0.17096E 02	0.27568E-01

TABLE IV. (Continued)

L/D= 0.20000E 01
D/T= 0.60000E 03
K= 0.25000E 00
N= 0.60000E 01
NU= 0.50000E 00
AREA/A/T= 0.79365E-01
ZBAR/A/T= 0.26455E-02
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43949E-01	0.77744E-05	0.12555E-03	0.18204E-08
0.25000E-01	0.91146E-01	0.29591E-04	0.52284E-03	0.21994E-07
0.37500E-01	0.14195E 00	0.65451E-04	0.12616E-02	0.10437E-06
0.50000E-01	0.19758E 00	0.11535E-03	0.24634E-02	0.32184E-06
0.62500E-01	0.25822E 00	0.17930E-03	0.43013E-02	0.77634E-06
0.75000E-01	0.32506E 00	0.25728E-03	0.70003E-02	0.15989E-05
0.87500E-01	0.40005E 00	0.34931E-03	0.10837E-01	0.29494E-05
0.10000E 00	0.48476E 00	0.45539E-03	0.16140E-01	0.50170E-05
0.11250E 00	0.57810E 00	0.57550E-03	0.23289E-01	0.80199E-05
0.12500E 00	0.67972E 00	0.70966E-03	0.32716E-01	0.12205E-04
0.15000E 00	0.90733E 00	0.10201E-02	0.60390E-01	0.25256E-04
0.17500E 00	0.11671E 01	0.13867E-02	0.10365E 00	0.46729E-04
0.20000E 00	0.14593E 01	0.18095E-02	0.16781E 00	0.79646E-04
0.22500E 00	0.17857E 01	0.22884E-02	0.25902E 00	0.12749E-03
0.25000E 00	0.21475E 01	0.28236E-02	0.38425E 00	0.19423E-03
0.27500E 00	0.25452E 01	0.34149E-02	0.55130E 00	0.28426E-03
0.30000E 00	0.29781E 01	0.40623E-02	0.76879E 00	0.40247E-03
0.32500E 00	0.34459E 01	0.47660E-02	0.10462E 01	0.55421E-03
0.35000E 00	0.39485E 01	0.55258E-02	0.13938E 01	0.74529E-03
0.37500E 00	0.44860E 01	0.63417E-02	0.18226E 01	0.98199E-03
0.40000E 00	0.50588E 01	0.72139E-02	0.23447E 01	0.12710E-02
0.42500E 00	0.56681E 01	0.81422E-02	0.29728E 01	0.16197E-02
0.45000E 00	0.63142E 01	0.91267E-02	0.37204E 01	0.20355E-02
0.47500E 00	0.69965E 01	0.10167E-01	0.46021E 01	0.25267E-02
0.50000E 00	0.77148E 01	0.11264E-01	0.56330E 01	0.31019E-02
0.52500E 00	0.84690E 01	0.12417E-01	0.68293E 01	0.37700E-02
0.55000E 00	0.92589E 01	0.13626E-01	0.82077E 01	0.45408E-02
0.57500E 00	0.10085E 02	0.14892E-01	0.97861E 01	0.54241E-02
0.60000E 00	0.10946E 02	0.16213E-01	0.11583E 02	0.64304E-02
0.62500E 00	0.11843E 02	0.17591E-01	0.13618E 02	0.75706E-02
0.65000E 00	0.12776E 02	0.19025E-01	0.15911E 02	0.88562E-02
0.67500E 00	0.13744E 02	0.20515E-01	0.18483E 02	0.10299E-01
0.70000E 00	0.14749E 02	0.22061E-01	0.21356E 02	0.11911E-01
0.72500E 00	0.15788E 02	0.23663E-01	0.24553E 02	0.13706E-01
0.75000E 00	0.16864E 02	0.25322E-01	0.28097E 02	0.15695E-01
0.77500E 00	0.17975E 02	0.27036E-01	0.32013E 02	0.17895E-01
0.80000E 00	0.19122E 02	0.28807E-01	0.36325E 02	0.20317E-01

TABLE IV. (Continued)

L/D= 0.20000E 01
D/T= 0.80000E 03
K= 0.25000E 00
N= 0.60000E 01
NU= 0.50000E 00
AREA/A/T= 0.59524E-01
ZBAR/A/T= 0.19841E-02
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43926E-01	0.56896E-05	0.12548E-03	0.11718E-08
0.25000E-01	0.90964E-01	0.21911E-04	0.52257E-03	0.15685E-07
0.37500E-01	0.14182E 00	0.48664E-04	0.12610E-02	0.76374E-07
0.50000E-01	0.19746E 00	0.85950E-04	0.24623E-02	0.23786E-06
0.62500E-01	0.25817E 00	0.13377E-03	0.42996E-02	0.57653E-06
0.75000E-01	0.32502E 00	0.19212E-03	0.69979E-02	0.11906E-05
0.87500E-01	0.40000E 00	0.26100E-03	0.10834E-01	0.21999E-05
0.10000E 00	0.48472E 00	0.34041E-03	0.16136E-01	0.37464E-05
0.11250E 00	0.57805E 00	0.43035E-03	0.23284E-01	0.59935E-05
0.12500E 00	0.67968E 00	0.53083E-03	0.32709E-01	0.91264E-05
0.15000E 00	0.90730E 00	0.76338E-03	0.60380E-01	0.18900E-04
0.17500E 00	0.11671E 01	0.10381E-02	0.10364E 00	0.34986E-04
0.20000E 00	0.14592E 01	0.13549E-02	0.16780E 00	0.59650E-04
0.22500E 00	0.17856E 01	0.17138E-02	0.25900E 00	0.95508E-04
0.25000E 00	0.21473E 01	0.21149E-02	0.38423E 00	0.14552E-03
0.27500E 00	0.25451E 01	0.25580E-02	0.55127E 00	0.21301E-03
0.30000E 00	0.29780E 01	0.30434E-02	0.76875E 00	0.30162E-03
0.32500E 00	0.34458E 01	0.35708E-02	0.10461E 01	0.41538E-03
0.35000E 00	0.39485E 01	0.41404E-02	0.13937E 01	0.55863E-03
0.37500E 00	0.44859E 01	0.47521E-02	0.18226E 01	0.73609E-03
0.40000E 00	0.50586E 01	0.54059E-02	0.23446E 01	0.95280E-03
0.42500E 00	0.56679E 01	0.61018E-02	0.29727E 01	0.12142E-02
0.45000E 00	0.63140E 01	0.68399E-02	0.37204E 01	0.15260E-02
0.47500E 00	0.69964E 01	0.76201E-02	0.46020E 01	0.18943E-02
0.50000E 00	0.77147E 01	0.84425E-02	0.56329E 01	0.23255E-02
0.52500E 00	0.84689E 01	0.93069E-02	0.68291E 01	0.28266E-02
0.55000E 00	0.92588E 01	0.10214E-01	0.82076E 01	0.34045E-02
0.57500E 00	0.10085E 02	0.11162E-01	0.97860E 01	0.40668E-02
0.60000E 00	0.10946E 02	0.12153E-01	0.11583E 02	0.48214E-02
0.62500E 00	0.11843E 02	0.13186E-01	0.13618E 02	0.56764E-02
0.65000E 00	0.12776E 02	0.14261E-01	0.15911E 02	0.66404E-02
0.67500E 00	0.13744E 02	0.15378E-01	0.18483E 02	0.77222E-02
0.70000E 00	0.14748E 02	0.16538E-01	0.21356E 02	0.89311E-02
0.72500E 00	0.15788E 02	0.17739E-01	0.24553E 02	0.10277E-01
0.75000E 00	0.16864E 02	0.18983E-01	0.28097E 02	0.11769E-01
0.77500E 00	0.17975E 02	0.20269E-01	0.32012E 02	0.13418E-01
0.80000E 00	0.19121E 02	0.21596E-01	0.36325E 02	0.15235E-01

TABLE IV. (Continued)

L/D= 0.20000E 01
D/T= 0.10000E 04
K= 0.25000E 00
N= 0.70000E 01
NU= 0.50000E 00
AREA/A/T= 0.47619E-01
ZBAR/A/T= 0.15873E-02
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.44216E-01	0.67230E-05	0.12515E-03	0.82392E-09
0.25000E-01	0.90747E-01	0.22155E-04	0.53492E-03	0.11338E-07
0.37500E-01	0.14171E 00	0.46295E-04	0.13497E-02	0.55419E-07
0.50000E-01	0.20143E 00	0.79144E-04	0.27819E-02	0.17269E-06
0.62500E-01	0.27306E 00	0.12070E-03	0.51358E-02	0.41853E-06
0.75000E-01	0.35515E 00	0.17097E-03	0.88078E-02	0.86405E-06
0.87500E-01	0.44956E 00	0.22994E-03	0.14286E-01	0.15961E-05
0.10000E 00	0.55629E 00	0.29763E-03	0.22151E-01	0.27174E-05
0.11250E 00	0.67475E 00	0.37402E-03	0.33074E-01	0.43462E-05
0.12500E 00	0.80481E 00	0.45912E-03	0.47820E-01	0.66167E-05
0.15000E 00	0.11002E 01	0.65544E-03	0.92296E-01	0.13698E-04
0.17500E 00	0.14440E 01	0.88661E-03	0.16353E 00	0.25349E-04
0.20000E 00	0.18352E 01	0.11526E-02	0.27095E 00	0.43209E-04
0.22500E 00	0.22737E 01	0.14534E-02	0.42544E 00	0.69172E-04
0.25000E 00	0.27595E 01	0.17891E-02	0.63938E 00	0.10538E-03
0.27500E 00	0.32931E 01	0.21596E-02	0.92660E 00	0.15423E-03
0.30000E 00	0.38765E 01	0.25649E-02	0.13024E 01	0.21837E-03
0.32500E 00	0.45093E 01	0.30051E-02	0.17836E 01	0.30069E-03
0.35000E 00	0.51908E 01	0.34801E-02	0.23884E 01	0.40436E-03
0.37500E 00	0.59210E 01	0.39899E-02	0.31365E 01	0.53277E-03
0.40000E 00	0.66997E 01	0.45346E-02	0.40492E 01	0.68959E-03
0.42500E 00	0.75269E 01	0.51141E-02	0.51490E 01	0.87871E-03
0.45000E 00	0.84027E 01	0.57285E-02	0.64602E 01	0.11043E-02
0.47500E 00	0.93269E 01	0.63776E-02	0.80084E 01	0.13708E-02
0.50000E 00	0.10300E 02	0.70616E-02	0.98205E 01	0.16828E-02
0.52500E 00	0.11321E 02	0.77805E-02	0.11925E 02	0.20452E-02
0.55000E 00	0.12390E 02	0.85342E-02	0.14353E 02	0.24633E-02
0.57500E 00	0.13508E 02	0.93227E-02	0.17134E 02	0.29425E-02
0.60000E 00	0.14675E 02	0.10146E-01	0.20302E 02	0.34883E-02
0.62500E 00	0.15890E 02	0.11004E-01	0.23892E 02	0.41068E-02
0.65000E 00	0.17154E 02	0.11897E-01	0.27940E 02	0.48042E-02
0.67500E 00	0.18467E 02	0.12825E-01	0.32482E 02	0.55867E-02
0.70000E 00	0.19830E 02	0.13788E-01	0.37558E 02	0.64612E-02
0.72500E 00	0.21241E 02	0.14785E-01	0.43207E 02	0.74345E-02
0.75000E 00	0.22701E 02	0.15818E-01	0.49473E 02	0.85139E-02
0.77500E 00	0.24210E 02	0.16885E-01	0.56397E 02	0.97068E-02
0.80000E 00	0.25768E 02	0.17987E-01	0.64025E 02	0.11021E-01

TABLE IV. (Concluded)

L/D= 0.20000E 01
D/T= 0.12000E 04
K= 0.25000E 00
N= 0.70000E 01
NU= 0.50000E 00
AREA/A/T= 0.39683E-01
ZBAR/A/T= 0.13228E-02
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.44213E-01	0.52735E-05	0.12512E-03	0.64876E-09
0.25000E-01	0.90688E-01	0.17804E-04	0.53479E-03	0.92740E-08
0.37500E-01	0.14155E 00	0.37592E-04	0.13494E-02	0.45737E-07
0.50000E-01	0.20138E 00	0.64637E-04	0.27814E-02	0.14302E-06
0.62500E-01	0.27301E 00	0.98939E-04	0.51351E-02	0.34724E-06
0.75000E-01	0.35509E 00	0.14050E-03	0.88067E-02	0.71763E-06
0.87500E-01	0.44952E 00	0.18932E-03	0.14284E-01	0.13265E-05
0.10000E 00	0.55626E 00	0.24539E-03	0.22149E-01	0.22595E-05
0.11250E 00	0.67473E 00	0.30872E-03	0.33071E-01	0.36150E-05
0.12500E 00	0.80478E 00	0.37931E-03	0.47817E-01	0.55048E-05
0.15000E 00	0.11002E 01	0.54226E-03	0.92292E-01	0.11400E-04
0.17500E 00	0.14439E 01	0.73423E-03	0.16353E 00	0.21102E-04
0.20000E 00	0.18352E 01	0.95524E-03	0.27094E 00	0.35976E-04
0.22500E 00	0.22737E 01	0.12053E-02	0.42543E 00	0.57599E-04
0.25000E 00	0.27595E 01	0.14843E-02	0.63937E 00	0.87756E-04
0.27500E 00	0.32930E 01	0.17924E-02	0.92658E 00	0.12845E-03
0.30000E 00	0.38765E 01	0.21295E-02	0.13024E 01	0.18187E-03
0.32500E 00	0.45092E 01	0.24957E-02	0.17836E 01	0.25045E-03
0.35000E 00	0.51908E 01	0.28909E-02	0.23883E 01	0.33681E-03
0.37500E 00	0.59209E 01	0.33151E-02	0.31365E 01	0.44379E-03
0.40000E 00	0.66997E 01	0.37683E-02	0.40491E 01	0.57443E-03
0.42500E 00	0.75269E 01	0.42506E-02	0.51490E 01	0.73199E-03
0.45000E 00	0.84027E 01	0.47619E-02	0.64602E 01	0.91993E-03
0.47500E 00	0.93269E 01	0.53022E-02	0.80083E 01	0.11419E-02
0.50000E 00	0.10300E 02	0.58715E-02	0.98205E 01	0.14019E-02
0.52500E 00	0.11321E 02	0.64699E-02	0.11925E 02	0.17039E-02
0.55000E 00	0.12390E 02	0.70973E-02	0.14353E 02	0.20522E-02
0.57500E 00	0.13508E 02	0.77538E-02	0.17134E 02	0.24514E-02
0.60000E 00	0.14675E 02	0.84392E-02	0.20302E 02	0.29062E-02
0.62500E 00	0.15890E 02	0.91537E-02	0.23892E 02	0.34216E-02
0.65000E 00	0.17154E 02	0.98972E-02	0.27940E 02	0.40026E-02
0.67500E 00	0.18467E 02	0.10670E-01	0.32482E 02	0.46546E-02
0.70000E 00	0.19830E 02	0.11471E-01	0.37557E 02	0.53832E-02
0.72500E 00	0.21241E 02	0.12302E-01	0.43207E 02	0.61942E-02
0.75000E 00	0.22701E 02	0.13162E-01	0.49472E 02	0.70936E-02
0.77500E 00	0.24210E 02	0.14050E-01	0.56397E 02	0.80875E-02
0.80000E 00	0.25768E 02	0.14968E-01	0.64025E 02	0.91823E-02

TABLE V. PARAMETER STUDY FOR GREENSPON THEORY
WITH STIFFENERS L/D = 4

L/D= 0.40000E 01
D/T= 0.10000E 03
K= 0.25000E 00
N= 0.30000E 01
NU= 0.50000E 00
AREA/A/T= 0.47619E 00
ZBAR/A/T= 0.79365E-02
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43182E-01	0.21595E-04	0.12456E-03	0.96343E-08
0.25000E-01	0.87667E-01	0.64962E-04	0.49755E-03	0.58790E-07
0.37500E-01	0.13230E 00	0.13010E-03	0.11204E-02	0.20737E-06
0.50000E-01	0.17720E 00	0.21701E-03	0.19977E-02	0.55467E-06
0.62500E-01	0.22246E 00	0.32569E-03	0.31374E-02	0.12393E-05
0.75000E-01	0.26824E 00	0.45615E-03	0.45505E-02	0.24394E-05
0.87500E-01	0.31469E 00	0.60837E-03	0.62514E-02	0.43722E-05
0.10000E 00	0.36176E 00	0.78237E-03	0.82576E-02	0.72946E-05
0.11250E 00	0.40944E 00	0.97813E-03	0.10590E-01	0.11503E-04
0.12500E 00	0.45816E 00	0.11957E-02	0.13272E-01	0.17332E-04
0.15000E 00	0.56058E 00	0.16961E-02	0.19800E-01	0.35393E-04
0.17500E 00	0.66939E 00	0.22835E-02	0.28097E-01	0.64949E-04
0.20000E 00	0.78379E 00	0.29581E-02	0.38471E-01	0.11010E-03
0.22500E 00	0.90359E 00	0.37198E-02	0.51284E-01	0.17558E-03
0.25000E 00	0.10287E 01	0.45685E-02	0.66946E-01	0.26675E-03
0.27500E 00	0.11593E 01	0.55043E-02	0.85921E-01	0.38961E-03
0.30000E 00	0.12964E 01	0.65272E-02	0.10872E 00	0.55076E-03
0.32500E 00	0.14419E 01	0.76372E-02	0.13592E 00	0.75747E-03
0.35000E 00	0.15969E 01	0.88343E-02	0.16813E 00	0.10176E-02
0.37500E 00	0.17605E 01	0.10118E-01	0.20603E 00	0.13397E-02
0.40000E 00	0.19328E 01	0.11490E-01	0.25032E 00	0.17329E-02
0.42500E 00	0.21138E 01	0.12948E-01	0.30180E 00	0.22069E-02
0.45000E 00	0.23031E 01	0.14493E-01	0.36128E 00	0.27722E-02
0.47500E 00	0.25005E 01	0.16126E-01	0.42964E 00	0.34398E-02
0.50000E 00	0.27061E 01	0.17846E-01	0.50781E 00	0.42213E-02
0.52500E 00	0.29197E 01	0.19652E-01	0.59676E 00	0.51291E-02
0.55000E 00	0.31412E 01	0.21546E-01	0.69754E 00	0.61760E-02
0.57500E 00	0.33707E 01	0.23527E-01	0.81122E 00	0.73757E-02
0.60000E 00	0.36082E 01	0.25595E-01	0.93894E 00	0.87422E-02
0.62500E 00	0.38535E 01	0.27750E-01	0.10819E 01	0.10290E-01
0.65000E 00	0.41068E 01	0.29992E-01	0.12413E 01	0.12036E-01
0.67500E 00	0.43679E 01	0.32321E-01	0.14185E 01	0.13994E-01
0.70000E 00	0.46370E 01	0.34737E-01	0.16147E 01	0.16183E-01
0.72500E 00	0.49139E 01	0.37241E-01	0.18315E 01	0.18619E-01
0.75000E 00	0.51988E 01	0.39831E-01	0.20701E 01	0.21320E-01
0.77500E 00	0.54915E 01	0.42509E-01	0.23323E 01	0.24305E-01
0.80000E 00	0.57922E 01	0.45273E-01	0.26193E 01	0.27592E-01

TABLE V. (Continued)

L/D= 0.40000E 01
D/T= 0.20000E 03
K= 0.2500CE 00
N= 0.30000E 01
NU= 0.500C0E 00
AREA/A/T= 0.23810E 00
ZBAR/A/T= 0.39683E-02
NUMBER OF STRINGERS= 8

W0/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.42988E-01	0.81203E-05	0.12430E-03	0.18372E-08
0.25000E-01	0.87043E-01	0.27126E-04	0.49652E-03	0.17333E-07
0.37500E-01	0.13200E 00	0.57018E-04	0.11181E-02	0.76230E-07
0.50000E-01	0.17702E 00	0.97796E-04	0.19936E-02	0.22795E-06
0.62500E-01	0.22232E 00	0.14946E-03	0.31309E-02	0.54162E-06
0.75000E-01	0.26810E 00	0.21201E-03	0.45412E-02	0.11060E-05
0.87500E-01	0.31458E 00	0.28544E-03	0.62388E-02	0.20297E-05
0.10000E 00	0.36165E 00	0.36976E-03	0.82411E-02	0.34407E-05
0.11250E 00	0.40932E 00	0.46497E-03	0.10569E-01	0.54870E-05
0.12500E 00	0.45800E 00	0.57106E-03	0.13247E-01	0.83361E-05
0.15000E 00	0.56042E 00	0.81590E-03	0.19763E-01	0.17211E-04
0.17500E 00	0.66922E 00	0.11043E-02	0.28046E-01	0.31800E-04
0.20000E 00	0.78361E 00	0.14362E-02	0.38406E-01	0.54152E-04
0.22500E 00	0.90339E 00	0.18117E-02	0.51200E-01	0.86631E-04
0.25000E 00	0.10285E 01	0.22307E-02	0.66843E-01	0.13192E-03
0.27500E 00	0.11589E 01	0.26933E-02	0.85796E-01	0.19300E-03
0.30000E 00	0.12956E 01	0.31994E-02	0.10858E 00	0.27319E-03
0.32500E 00	0.14412E 01	0.37490E-02	0.13575E 00	0.37612E-03
0.35000E 00	0.15963E 01	0.43422E-02	0.16793E 00	0.50572E-03
0.37500E 00	0.17599E 01	0.49789E-02	0.20579E 00	0.66624E-03
0.40000E 00	0.19322E 01	0.56592E-02	0.25006E 00	0.86226E-03
0.42500E 00	0.21132E 01	0.63830E-02	0.30150E 00	0.10987E-02
0.45000E 00	0.23026E 01	0.71504E-02	0.36095E 00	0.13806E-02
0.47500E 00	0.25000E 01	0.79613E-02	0.42927E 00	0.17137E-02
0.50000E 00	0.27056E 01	0.88157E-02	0.50740E 00	0.21037E-02
0.52500E 00	0.29192E 01	0.97137E-02	0.59631E 00	0.25567E-02
0.55000E 00	0.31407E 01	0.10655E-01	0.69704E 00	0.30793E-02
0.57500E 00	0.33702E 01	0.11640E-01	0.81068E 00	0.36782E-02
0.60000E 00	0.36077E 01	0.12669E-01	0.93835E 00	0.43604E-02
0.62500E 00	0.38530E 01	0.13741E-01	0.10812E 01	0.51335E-02
0.65000E 00	0.41063E 01	0.14857E-01	0.12406E 01	0.60050E-02
0.67500E 00	0.43674E 01	0.16016E-01	0.14177E 01	0.69831E-02
0.70000E 00	0.46365E 01	0.17219E-01	0.16139E 01	0.80761E-02
0.72500E 00	0.49134E 01	0.18465E-01	0.18306E 01	0.92926E-02
0.75000E 00	0.51983E 01	0.19755E-01	0.20692E 01	0.10642E-01
0.77500E 00	0.54910E 01	0.21088E-01	0.23313E 01	0.12133E-01
0.80000E 00	0.57917E 01	0.22465E-01	0.26183E 01	0.13775E-01

TABLE V. (Continued)

L/D= 0.40000E 01
D/T= 0.40000E 03
K= 0.2500CE 00
N= 0.4000CE 01
NU= 0.500CCE 00
AREA/A/T= 0.11905E 00
ZBAR/A/T= 0.19841E-02
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43505E-01	0.52891E-05	0.12443E-03	0.10288E-08
0.25000E-01	0.88023E-01	0.20729E-04	0.50088E-03	0.13686E-07
0.37500E-01	0.13401E 00	0.46318E-04	0.11417E-02	0.66664E-07
0.50000E-01	0.18078E 00	0.82059E-04	0.20691E-02	0.20777E-06
0.62500E-01	0.22846E 00	0.12795E-03	0.33156E-02	0.50391E-06
0.75000E-01	0.27853E 00	0.18399E-03	0.49236E-02	0.10411E-05
0.87500E-01	0.33107E 00	0.25018E-03	0.69455E-02	0.19246E-05
0.10000E 00	0.38638E 00	0.32652E-03	0.94439E-02	0.32785E-05
0.11250E 00	0.44523E 00	0.41302E-03	0.12491E-01	0.52462E-05
0.12500E 00	0.50712E 00	0.50966E-03	0.16170E-01	0.79903E-05
0.15000E 00	0.63961E 00	0.73340E-03	0.25803E-01	0.16553E-04
0.17500E 00	0.78342E 00	0.99773E-03	0.39204E-01	0.30649E-04
0.20000E 00	0.93847E 00	0.13027E-02	0.57395E-01	0.52265E-04
0.22500E 00	0.11052E 01	0.16482E-02	0.81560E-01	0.83696E-04
0.25000E 00	0.12841E 01	0.20344E-02	0.11304E 00	0.12754E-03
0.27500E 00	0.14758E 01	0.24611E-02	0.15334E 00	0.18671E-03
0.30000E 00	0.16827E 01	0.29285E-02	0.20413E 00	0.26440E-03
0.32500E 00	0.19041E 01	0.34364E-02	0.26723E 00	0.36415E-03
0.35000E 00	0.21408E 01	0.39850E-02	0.34462E 00	0.48976E-03
0.37500E 00	0.23923E 01	0.45741E-02	0.43846E 00	0.64537E-03
0.40000E 00	0.26596E 01	0.52039E-02	0.55104E 00	0.83542E-03
0.42500E 00	0.29453E 01	0.58742E-02	0.68485E 00	0.10646E-02
0.45000E 00	0.32483E 01	0.65852E-02	0.84250E 00	0.13381E-02
0.47500E 00	0.35677E 01	0.73367E-02	0.10268E 01	0.16611E-02
0.50000E 00	0.39032E 01	0.81289E-02	0.12407E 01	0.20393E-02
0.52500E 00	0.42549E 01	0.89617E-02	0.14872E 01	0.24788E-02
0.55000E 00	0.46224E 01	0.98350E-02	0.17698E 01	0.29857E-02
0.57500E 00	0.50058E 01	0.10749E-01	0.20917E 01	0.35666E-02
0.60000E 00	0.54050E 01	0.11704E-01	0.24566E 01	0.42285E-02
0.62500E 00	0.58199E 01	0.12699E-01	0.28683E 01	0.49784E-02
0.65000E 00	0.62506E 01	0.13734E-01	0.33306E 01	0.58240E-02
0.67500E 00	0.66969E 01	0.14811E-01	0.38477E 01	0.67729E-02
0.70000E 00	0.71589E 01	0.15928E-01	0.44237E 01	0.78334E-02
0.72500E 00	0.76365E 01	0.17085E-01	0.50631E 01	0.90138E-02
0.75000E 00	0.81298E 01	0.18284E-01	0.57704E 01	0.10323E-01
0.77500E 00	0.86387E 01	0.19522E-01	0.65504E 01	0.11769E-01
0.80000E 00	0.91633E 01	0.20802E-01	0.74079E 01	0.13363E-01

L/D= 0.40000E 01
D/T= 0.60000E 03
K= 0.25000E 00
N= 0.40000E 01
NU= 0.50000E 00
AREA/A/T= 0.79365E-01
ZBAR/A/T= 0.13228E-02
NUMBER OF STRINGERS= 8

TABLE V. (Continued)

W0/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43503E-01	0.34785E-05	0.12439E-03	0.60033E-09
0.25000E-01	0.87752E-01	0.13724E-04	0.50073E-03	0.87788E-08
0.37500E-01	0.13370E 00	0.30736E-04	0.11413E-02	0.43658E-07
0.50000E-01	0.18059E 00	0.54516E-04	0.20685E-02	0.13710E-06
0.62500E-01	0.22833E 00	0.85062E-04	0.33147E-02	0.33372E-06
0.75000E-01	0.27841E 00	0.12238E-03	0.49223E-02	0.69086E-06
0.87500E-01	0.33098E 00	0.16646E-03	0.69437E-02	0.12786E-05
0.10000E 00	0.38631E 00	0.21730E-03	0.94415E-02	0.21798E-05
0.11250E 00	0.44519E 00	0.27492E-03	0.12488E-01	0.34900E-05
0.12500E 00	0.50708E 00	0.33930E-03	0.16166E-01	0.53176E-05
0.15000E 00	0.63957E 00	0.48836E-03	0.25798E-01	0.11022E-04
0.17500E 00	0.78340E 00	0.66449E-03	0.39197E-01	0.20414E-04
0.20000E 00	0.93844E 00	0.86769E-03	0.57386E-01	0.34818E-04
0.22500E 00	0.11051E 01	0.10980E-02	0.81548E-01	0.55765E-04
0.25000E 00	0.12840E 01	0.13553E-02	0.11303E 00	0.84988E-04
0.27500E 00	0.14757E 01	0.16397E-02	0.15332E 00	0.12442E-03
0.30000E 00	0.16826E 01	0.19512E-02	0.20411E 00	0.17621E-03
0.32500E 00	0.19040E 01	0.22897E-02	0.26720E 00	0.24269E-03
0.35000E 00	0.21407E 01	0.26553E-02	0.34459E 00	0.32642E-03
0.37500E 00	0.23922E 01	0.30480E-02	0.43842E 00	0.43015E-03
0.40000E 00	0.26594E 01	0.34677E-02	0.55100E 00	0.55683E-03
0.42500E 00	0.29452E 01	0.39145E-02	0.68480E 00	0.70963E-03
0.45000E 00	0.32481E 01	0.43884E-02	0.84245E 00	0.89191E-03
0.47500E 00	0.35676E 01	0.48893E-02	0.10267E 01	0.11072E-02
0.50000E 00	0.39032E 01	0.54174E-02	0.12406E 01	0.13594E-02
0.52500E 00	0.42548E 01	0.59724E-02	0.14872E 01	0.16523E-02
0.55000E 00	0.46223E 01	0.65546E-02	0.17697E 01	0.19902E-02
0.57500E 00	0.50057E 01	0.71638E-02	0.20916E 01	0.23775E-02
0.60000E 00	0.54049E 01	0.78001E-02	0.24565E 01	0.28187E-02
0.62500E 00	0.58199E 01	0.84634E-02	0.28682E 01	0.33186E-02
0.65000E 00	0.62505E 01	0.91539E-02	0.33305E 01	0.38823E-02
0.67500E 00	0.66968E 01	0.98713E-02	0.38476E 01	0.45149E-02
0.70000E 00	0.71588E 01	0.10616E-01	0.44236E 01	0.52219E-02
0.72500E 00	0.76365E 01	0.11388E-01	0.50630E 01	0.60087E-02
0.75000E 00	0.81298E 01	0.12186E-01	0.57703E 01	0.68814E-02
0.77500E 00	0.86387E 01	0.13012E-01	0.65502E 01	0.78457E-02
0.80000E 00	0.91632E 01	0.13865E-01	0.74077E 01	0.89081E-02

TABLE V. (Continued)

L/D= 0.40000E 01
D/T= 0.80000E 03
K= 0.25000E 00
N= 0.40000E 01
NU= 0.50000E 00
AREA/A/T= 0.59524E-01
ZBAR/A/T= 0.99206E-03
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43502E-01	0.25911E-05	0.12438E-03	0.42770E-09
0.25000E-01	0.87690E-01	0.10257E-04	0.50068E-03	0.64927E-08
0.37500E-01	0.13347E 00	0.22999E-04	0.11412E-02	0.32535E-07
0.50000E-01	0.18037E 00	0.40816E-04	0.20683E-02	0.10245E-06
0.62500E-01	0.22817E 00	0.63707E-04	0.33144E-02	0.24970E-06
0.75000E-01	0.27831E 00	0.91675E-04	0.49218E-02	0.51728E-06
0.87500E-01	0.33089E 00	0.12472E-03	0.69431E-02	0.95777E-06
0.10000E 00	0.38623E 00	0.16283E-03	0.94406E-02	0.16333E-05
0.11250E 00	0.44511E 00	0.20603E-03	0.12487E-01	0.26155E-05
0.12500E 00	0.50703E 00	0.25430E-03	0.16165E-01	0.39857E-05
0.15000E 00	0.63957E 00	0.36606E-03	0.25796E-01	0.82626E-05
0.17500E 00	0.78338E 00	0.49812E-03	0.39194E-01	0.15305E-04
0.20000E 00	0.93842E 00	0.65048E-03	0.57383E-01	0.26107E-04
0.22500E 00	0.11051E 01	0.82315E-03	0.81544E-01	0.41815E-04
0.25000E 00	0.12840E 01	0.10161E-02	0.11302E 00	0.63729E-04
0.27500E 00	0.14757E 01	0.12294E-02	0.15332E 00	0.93302E-04
0.30000E 00	0.16826E 01	0.14629E-02	0.20410E 00	0.13214E-03
0.32500E 00	0.19040E 01	0.17168E-02	0.26719E 00	0.18200E-03
0.35000E 00	0.21407E 01	0.19910E-02	0.34458E 00	0.24479E-03
0.37500E 00	0.23921E 01	0.22854E-02	0.43841E 00	0.32259E-03
0.40000E 00	0.26593E 01	0.26002E-02	0.55099E 00	0.41759E-03
0.42500E 00	0.29452E 01	0.29353E-02	0.68479E 00	0.53219E-03
0.45000E 00	0.32481E 01	0.32907E-02	0.84243E 00	0.66889E-03
0.47500E 00	0.35675E 01	0.36663E-02	0.10267E 01	0.83038E-03
0.50000E 00	0.39031E 01	0.40623E-02	0.12406E 01	0.10195E-02
0.52500E 00	0.42548E 01	0.44786E-02	0.14871E 01	0.12392E-02
0.55000E 00	0.46223E 01	0.49152E-02	0.17697E 01	0.14926E-02
0.57500E 00	0.50057E 01	0.53720E-02	0.20916E 01	0.17830E-02
0.60000E 00	0.54049E 01	0.58492E-02	0.24565E 01	0.21139E-02
0.62500E 00	0.58198E 01	0.63467E-02	0.28682E 01	0.24889E-02
0.65000E 00	0.62505E 01	0.68645E-02	0.33305E 01	0.29116E-02
0.67500E 00	0.66968E 01	0.74025E-02	0.38476E 01	0.33861E-02
0.70000E 00	0.71588E 01	0.79609E-02	0.44236E 01	0.39163E-02
0.72500E 00	0.76365E 01	0.85396E-02	0.50630E 01	0.45064E-02
0.75000E 00	0.81297E 01	0.91386E-02	0.57703E 01	0.51609E-02
0.77500E 00	0.86386E 01	0.97579E-02	0.65502E 01	0.58841E-02
0.80000E 00	0.91632E 01	0.10397E-01	0.74076E 01	0.66809E-02

TABLE V. (Continued)

L/D= 0.40000E 01
D/T= 0.10000E 04
K= 0.25000E 00
N= 0.50000E 01
NU= 0.50000E 00
AREA/A/T= 0.47619E-01
ZBAR/A/T= 0.79365E-03
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.44255E-01	0.11957E-05	0.12479E-03	0.17332E-09
0.25000E-01	0.87859E-01	0.45685E-05	0.50828E-03	0.26675E-08
0.37500E-01	0.13195E 00	0.10118E-04	0.11821E-02	0.13397E-07
0.50000E-01	0.18005E 00	0.17846E-04	0.22016E-02	0.42213E-07
0.62500E-01	0.23366E 00	0.27750E-04	0.36463E-02	0.10290E-06
0.75000E-01	0.29254E 00	0.39831E-04	0.56192E-02	0.21320E-06
0.87500E-01	0.35623E 00	0.54090E-04	0.82474E-02	0.39476E-06
0.10000E 00	0.42458E 00	0.70526E-04	0.11682E-01	0.67318E-06
0.11250E 00	0.49753E 00	0.89139E-04	0.16097E-01	0.10780E-05
0.12500E 00	0.57499E 00	0.10993E-03	0.21692E-01	0.16427E-05
0.15000E 00	0.74369E 00	0.15804E-03	0.37335E-01	0.34053E-05
0.17500E 00	0.93161E 00	0.21486E-03	0.60676E-01	0.63076E-05
0.20000E 00	0.11449E 01	0.28039E-03	0.94164E-01	0.10759E-04
0.22500E 00	0.13816E 01	0.35463E-03	0.14063E 00	0.17232E-04
0.25000E 00	0.16423E 01	0.43757E-03	0.20328E 00	0.26263E-04
0.27500E 00	0.19276E 01	0.52923E-03	0.28571E 00	0.38449E-04
0.30000E 00	0.22373E 01	0.62959E-03	0.39190E 00	0.54452E-04
0.32500E 00	0.25729E 01	0.73866E-03	0.52621E 00	0.74997E-04
0.35000E 00	0.29344E 01	0.85644E-03	0.69336E 00	0.10087E-03
0.37500E 00	0.33211E 01	0.98293E-03	0.89849E 00	0.13293E-03
0.40000E 00	0.37332E 01	0.11181E-02	0.11471E 01	0.17207E-03
0.42500E 00	0.41713E 01	0.12620E-02	0.14451E 01	0.21929E-03
0.45000E 00	0.46350E 01	0.14146E-02	0.17986E 01	0.27562E-03
0.47500E 00	0.51239E 01	0.15760E-02	0.22145E 01	0.34216E-03
0.50000E 00	0.56381E 01	0.17460E-02	0.26997E 01	0.42007E-03
0.52500E 00	0.61775E 01	0.19247E-02	0.32616E 01	0.51059E-03
0.55000E 00	0.67419E 01	0.21122E-02	0.39079E 01	0.61501E-03
0.57500E 00	0.73313E 01	0.23084E-02	0.46470E 01	0.73468E-03
0.60000E 00	0.79458E 01	0.25132E-02	0.54873E 01	0.87102E-03
0.62500E 00	0.85853E 01	0.27268E-02	0.64378E 01	0.10255E-02
0.65000E 00	0.92498E 01	0.29491E-02	0.75078E 01	0.11997E-02
0.67500E 00	0.99392E 01	0.31801E-02	0.87070E 01	0.13952E-02
0.70000E 00	0.10654E 02	0.34198E-02	0.10045E 02	0.16136E-02
0.72500E 00	0.11393E 02	0.36682E-02	0.11534E 02	0.18568E-02
0.75000E 00	0.12157E 02	0.39253E-02	0.13182E 02	0.21264E-02
0.77500E 00	0.12947E 02	0.41911E-02	0.15003E 02	0.24244E-02
0.80000E 00	0.13761E 02	0.44657E-02	0.17007E 02	0.27527E-02

TABLE V. (Concluded)

L/D= 0.40000E 01
D/T= 0.12000E 04
K= 0.25000E 00
N= 0.50000E 01
NU= 0.50000E 00
AREA/A/T= 0.39683E-01
ZBAR/A/T= 0.66138E-03
NUMBER OF STRINGERS= 8

WC/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.44255E-01	0.98152E-06	0.12478E-03	0.14224E-09
0.25000E-01	0.87802E-01	0.37773E-05	0.50825E-03	0.22134E-08
0.37500E-01	0.13190E 00	0.83874E-05	0.11820E-02	0.11141E-07
0.50000E-01	0.18000E 00	0.14812E-04	0.22015E-02	0.35133E-07
0.62500E-01	0.23355E 00	0.23051E-04	0.36461E-02	0.85679E-07
0.75000E-01	0.29243E 00	0.33104E-04	0.56189E-02	0.17755E-06
0.87500E-01	0.35613E 00	0.44971E-04	0.82470E-02	0.32880E-06
0.10000E 00	0.42446E 00	0.58652E-04	0.11681E-01	0.56075E-06
0.11250E 00	0.49742E 00	0.74148E-04	0.16097E-01	0.89803E-06
0.12500E 00	0.57499E 00	0.91458E-04	0.21691E-01	0.13685E-05
0.15000E 00	0.74366E 00	0.13152E-03	0.37334E-01	0.28371E-05
0.17500E 00	0.93160E 00	0.17884E-03	0.60674E-01	0.52554E-05
0.20000E 00	0.11448E 01	0.23342E-03	0.94162E-01	0.89645E-05
0.22500E 00	0.13816E 01	0.29525E-03	0.14063E 00	0.14358E-04
0.25000E 00	0.16423E 01	0.36435E-03	0.20328E 00	0.21883E-04
0.27500E 00	0.19275E 01	0.44070E-03	0.28571E 00	0.32037E-04
0.30000E 00	0.22373E 01	0.52430E-03	0.39190E 00	0.45373E-04
0.32500E 00	0.25728E 01	0.61516E-03	0.52620E 00	0.62493E-04
0.35000E 00	0.29343E 01	0.71329E-03	0.69336E 00	0.84054E-04
0.37500E 00	0.33211E 01	0.81866E-03	0.89848E 00	0.11076E-03
0.40000E 00	0.37331E 01	0.93130E-03	0.11471E 01	0.14339E-03
0.42500E 00	0.41713E 01	0.10512E-02	0.14451E 01	0.18273E-03
0.45000E 00	0.46349E 01	0.11783E-02	0.17986E 01	0.22967E-03
0.47500E 00	0.51239E 01	0.13127E-02	0.22145E 01	0.28512E-03
0.50000E 00	0.56381E 01	0.14544E-02	0.26997E 01	0.35004E-03
0.52500E 00	0.61774E 01	0.16033E-02	0.32615E 01	0.42548E-03
0.55000E 00	0.67419E 01	0.17595E-02	0.39079E 01	0.51249E-03
0.57500E 00	0.73313E 01	0.19229E-02	0.46470E 01	0.61221E-03
0.60000E 00	0.79458E 01	0.20936E-02	0.54873E 01	0.72583E-03
0.62500E 00	0.85853E 01	0.22716E-02	0.64378E 01	0.85456E-03
0.65000E 00	0.92498E 01	0.24568E-02	0.75078E 01	0.99971E-03
0.67500E 00	0.99392E 01	0.26493E-02	0.87069E 01	0.11626E-02
0.70000E 00	0.10654E 02	0.28490E-02	0.10045E 02	0.13446E-02
0.72500E 00	0.11393E 02	0.30560E-02	0.11534E 02	0.15473E-02
0.75000E 00	0.12157E 02	0.32702E-02	0.13182E 02	0.17720E-02
0.77500E 00	0.12947E 02	0.34917E-02	0.15003E 02	0.20203E-02
0.80000E 00	0.13761E 02	0.37204E-02	0.17007E 02	0.22939E-02

TABLE VI. PARAMETER STUDY FOR GREENSPON THEORY WITH STIFFENERS WITH VARIATION IN NUMBER OF STIFFENERS.

L/D= 0.40000E 01
D/T= 0.40000E 03
K= 0.25000E 00
N= 0.40000E 01
NU= 0.50000E 00
AREA/A/T= 0.11905E 00
ZBAR/A/T= 0.19841E-02
NUMBER OF STRINGERS= 8

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43505E-01	0.52891E-05	0.12443E-03	0.10288E-08
0.25000E-01	0.88023E-01	0.20729E-04	0.50088E-03	0.13686E-07
0.37500E-01	0.13401E 00	0.46318E-04	0.11417E-02	0.66664E-07
0.50000E-01	0.18078E 00	0.82059E-04	0.20691E-02	0.20777E-06
0.62500E-01	0.22846E 00	0.12795E-03	0.33156E-02	0.50391E-06
0.75000E-01	0.27853E 00	0.18399E-03	0.49236E-02	0.10411E-05
0.87500E-01	0.33107E 00	0.25018E-03	0.69455E-02	0.19246E-05
0.10000E 00	0.38638E 00	0.32652E-03	0.94439E-02	0.32785E-05
0.11250E 00	0.44523E 00	0.41302E-03	0.12491E-01	0.52462E-05
0.12500E 00	0.50712E 00	0.50966E-03	0.16170E-01	0.79903E-05
0.15000E 00	0.63961E 00	0.73340E-03	0.25803E-01	0.16553E-04
0.17500E 00	0.78342E 00	0.99773E-03	0.39204E-01	0.30649E-04
0.20000E 00	0.93847E 00	0.13027E-02	0.57395E-01	0.52265E-04
0.22500E 00	0.11052E 01	0.16482E-02	0.81560E-01	0.83696E-04
0.25000E 00	0.12841E 01	0.20344E-02	0.11304E 00	0.12754E-03
0.27500E 00	0.14758E 01	0.24611E-02	0.15334E 00	0.18671E-03
0.30000E 00	0.16827E 01	0.29285E-02	0.20413E 00	0.26440E-03
0.32500E 00	0.19041E 01	0.34364E-02	0.26723E 00	0.36415E-03
0.35000E 00	0.21408E 01	0.39850E-02	0.34462E 00	0.48976E-03
0.37500E 00	0.23923E 01	0.45741E-02	0.43846E 00	0.64537E-03
0.40000E 00	0.26596E 01	0.52039E-02	0.55104E 00	0.83542E-03
0.42500E 00	0.29453E 01	0.58742E-02	0.68485E 00	0.10646E-02
0.45000E 00	0.32483E 01	0.65852E-02	0.84250E 00	0.13381E-02
0.47500E 00	0.35677E 01	0.73367E-02	0.10268E 01	0.16611E-02
0.50000E 00	0.39032E 01	0.81289E-02	0.12407E 01	0.20393E-02
0.52500E 00	0.42549E 01	0.89617E-02	0.14872E 01	0.24788E-02
0.55000E 00	0.46224E 01	0.98350E-02	0.17698E 01	0.29857E-02
0.57500E 00	0.50058E 01	0.10749E-01	0.20917E 01	0.35666E-02
0.60000E 00	0.54050E 01	0.11704E-01	0.24566E 01	0.42285E-02
0.62500E 00	0.58199E 01	0.12699E-01	0.28683E 01	0.49784E-02
0.65000E 00	0.62506E 01	0.13734E-01	0.33306E 01	0.58240E-02
0.67500E 00	0.66969E 01	0.14811E-01	0.38477E 01	0.67729E-02
0.70000E 00	0.71589E 01	0.15928E-01	0.44237E 01	0.78334E-02
0.72500E 00	0.76365E 01	0.17085E-01	0.50631E 01	0.90138E-02
0.75000E 00	0.81298E 01	0.18284E-01	0.57704E 01	0.10323E-01
0.77500E 00	0.86387E 01	0.19522E-01	0.65504E 01	0.11769E-01
0.80000E 00	0.91633E 01	0.20802E-01	0.74079E 01	0.13363E-01

TABLE VI. (Continued)

L/D= 0.40000E 01
D/T= 0.40000E 03
K= 0.25000E 00
N= 0.40000E 01
NU= 0.50000E 00
AREA/A/T= 0.11905E 00
ZBAR/A/T= 0.19841E-02
NUMBER OF STRINGERS= 32

WC/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43505E-01	0.10443E-04	0.12443E-03	0.16321E-08
0.25000E-01	0.88023E-01	0.41042E-04	0.50088E-03	0.20622E-07
0.37500E-01	0.13401E 00	0.91798E-04	0.11417E-02	0.99224E-07
0.50000E-01	0.18078E 00	0.16271E-03	0.20691E-02	0.30784E-06
0.62500E-01	0.22846E 00	0.25378E-03	0.33156E-02	0.74501E-06
0.75000E-01	0.27853E 00	0.36500E-03	0.49236E-02	0.15375E-05
0.87500E-01	0.33107E 00	0.49638E-03	0.69455E-02	0.28400E-05
0.10000E 00	0.38638E 00	0.64792E-03	0.94439E-02	0.48357E-05
0.11250E 00	0.44523E 00	0.81961E-03	0.12491E-01	0.77356E-05
0.12500E 00	0.50712E 00	0.10115E-02	0.16170E-01	0.11779E-04
0.15000E 00	0.63961E 00	0.14556E-02	0.25803E-01	0.24395E-04
0.17500E 00	0.78342E 00	0.19804E-02	0.39204E-01	0.45160E-04
0.20000E 00	0.93847E 00	0.25858E-02	0.57395E-01	0.77002E-04
0.22500E 00	0.11052E 01	0.32719E-02	0.81560E-01	0.12330E-03
0.25000E 00	0.12841E 01	0.40386E-02	0.11304E 00	0.18788E-03
0.27500E 00	0.14758E 01	0.48859E-02	0.15334E 00	0.27502E-03
0.30000E 00	0.16827E 01	0.58138E-02	0.20413E 00	0.38946E-03
0.32500E 00	0.19041E 01	0.68223E-02	0.26723E 00	0.53637E-03
0.35000E 00	0.21408E 01	0.79115E-02	0.34462E 00	0.72138E-03
0.37500E 00	0.23923E 01	0.90813E-02	0.43846E 00	0.95057E-03
0.40000E 00	0.26596E 01	0.10332E-01	0.55104E 00	0.12305E-02
0.42500E 00	0.29453E 01	0.11663E-01	0.68485E 00	0.15681E-02
0.45000E 00	0.32483E 01	0.13074E-01	0.84250E 00	0.19708E-02
0.47500E 00	0.35677E 01	0.14567E-01	0.10268E 01	0.24465E-02
0.50000E 00	0.39032E 01	0.16140E-01	0.12407E 01	0.30036E-02
0.52500E 00	0.42549E 01	0.17793E-01	0.14872E 01	0.36508E-02
0.55000E 00	0.46224E 01	0.19527E-01	0.17698E 01	0.43973E-02
0.57500E 00	0.50058E 01	0.21342E-01	0.20917E 01	0.52529E-02
0.60000E 00	0.54050E 01	0.23238E-01	0.24566E 01	0.62277E-02
0.62500E 00	0.58199E 01	0.25214E-01	0.28683E 01	0.73322E-02
0.65000E 00	0.62506E 01	0.27270E-01	0.33306E 01	0.85775E-02
0.67500E 00	0.66969E 01	0.29408E-01	0.38477E 01	0.99751E-02
0.70000E 00	0.71589E 01	0.31626E-01	0.44237E 01	0.11537E-01
0.72500E 00	0.76365E 01	0.33924E-01	0.50631E 01	0.13275E-01
0.75000E 00	0.81298E 01	0.36303E-01	0.57704E 01	0.15203E-01
0.77500E 00	0.86387E 01	0.38763E-01	0.65504E 01	0.17334E-01
0.80000E 00	0.91633E 01	0.41303E-01	0.74079E 01	0.19681E-01

TABLE VI. (Continued)

L/D= 0.40000E 01
D/T= 0.40000E 03
K= 0.25000E 00
N= 0.40000E 01
NU= 0.50000E 00
AREA/A/T= 0.11905E 00
ZBAR/A/T= 0.19841E-02
NUMBER OF STRINGERS= 105

WO/A	VSH1	VST1	ISH1	IST1
0.12500E-01	0.43505E-01	0.34168E-04	0.12443E-03	0.53181E-08
0.25000E-01	0.88023E-01	0.13438E-03	0.50088E-03	0.67106E-07
0.37500E-01	0.13401E 00	0.30062E-03	0.11417E-02	0.32277E-06
0.50000E-01	0.18078E 00	0.53291E-03	0.20691E-02	0.10013E-05
0.62500E-01	0.22846E 00	0.83123E-03	0.33156E-02	0.24231E-05
0.75000E-01	0.27853E 00	0.11956E-02	0.49236E-02	0.50004E-05
0.87500E-01	0.33107E 00	0.16260E-02	0.69455E-02	0.92366E-05
0.10000E 00	0.38638E 00	0.21224E-02	0.94439E-02	0.15727E-04
0.11250E 00	0.44523E 00	0.26849E-02	0.12491E-01	0.25158E-04
0.12500E 00	0.50712E 00	0.33134E-02	0.16170E-01	0.38309E-04
0.15000E 00	0.63961E 00	0.47686E-02	0.25803E-01	0.79337E-04
0.17500E 00	0.78342E 00	0.64879E-02	0.39204E-01	0.14687E-03
0.20000E 00	0.93847E 00	0.84713E-02	0.57395E-01	0.25043E-03
0.22500E 00	0.11052E 01	0.10719E-01	0.81560E-01	0.40100E-03
0.25000E 00	0.12841E 01	0.13231E-01	0.11304E 00	0.61103E-03
0.27500E 00	0.14758E 01	0.16007E-01	0.15334E 00	0.89444E-03
0.30000E 00	0.16827E 01	0.19047E-01	0.20413E 00	0.12666E-02
0.32500E 00	0.19041E 01	0.22351E-01	0.26723E 00	0.17444E-02
0.35000E 00	0.21408E 01	0.25919E-01	0.34462E 00	0.23461E-02
0.37500E 00	0.23923E 01	0.29752E-01	0.43846E 00	0.30915E-02
0.40000E 00	0.26596E 01	0.33849E-01	0.55104E 00	0.40018E-02
0.42500E 00	0.29453E 01	0.38209E-01	0.68485E 00	0.50997E-02
0.45000E 00	0.32483E 01	0.42834E-01	0.84250E 00	0.64095E-02
0.47500E 00	0.35677E 01	0.47724E-01	0.10268E 01	0.79567E-02
0.50000E 00	0.39032E 01	0.52877E-01	0.12407E 01	0.97684E-02
0.52500E 00	0.42549E 01	0.58294E-01	0.14872E 01	0.11873E-01
0.55000E 00	0.46224E 01	0.63976E-01	0.17698E 01	0.14301E-01
0.57500E 00	0.50058E 01	0.69922E-01	0.20917E 01	0.17084E-01
0.60000E 00	0.54050E 01	0.76132E-01	0.24566E 01	0.20254E-01
0.62500E 00	0.58199E 01	0.82606E-01	0.28683E 01	0.23846E-01
0.65000E 00	0.62506E 01	0.89344E-01	0.33306E 01	0.27896E-01
0.67500E 00	0.66969E 01	0.96347E-01	0.38477E 01	0.32441E-01
0.70000E 00	0.71589E 01	0.10361E 00	0.44237E 01	0.37521E-01
0.72500E 00	0.76365E 01	0.11114E 00	0.50631E 01	0.43174E-01
0.75000E 00	0.81298E 01	0.11894E 00	0.57704E 01	0.49444E-01
0.77500E 00	0.86387E 01	0.12700E 00	0.65504E 01	0.56373E-01
0.80000E 00	0.91633E 01	0.13532E 00	0.74079E 01	0.64006E-01

the present calculations and dividing this number into the inner circumference of the shell. The specific input data and assumptions used in the computations are included below in Figure 8.

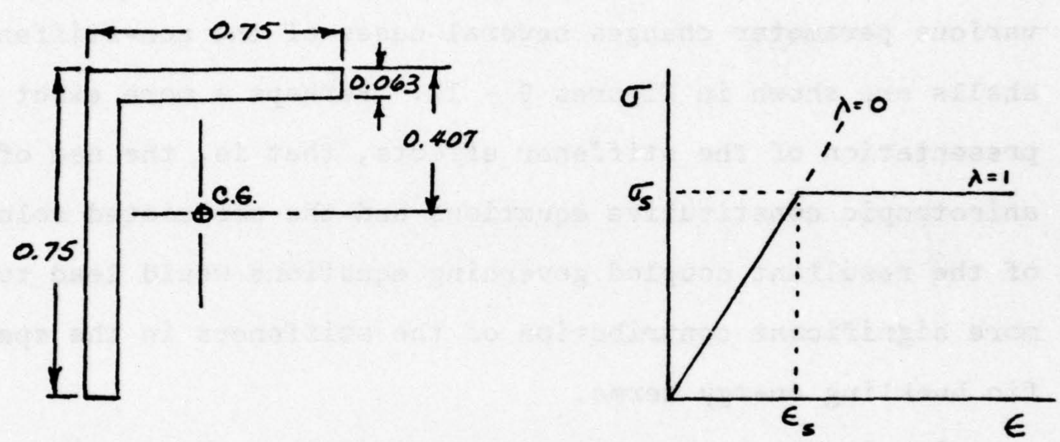


Figure 8. Stiffener Dimensions and Assumed Stress-Strain Curve.

The effect of the stiffener is seen by comparing the values of the VSH1 and VST1 or ISH1 and IST1 of Tables III - VI. In all cases the shell terms (VSH1,ISH1) are almost two orders of magnitude greater than the stiffener terms (VST1,IST1) which points out one of the interesting consequences of the results obtained, i.e., the shell itself is much stronger than is the influence of adding reinforcing stiffeners. This result occurs even though added stiffness

in the boundary attachments of the stiffeners has been included in the theory. This is further demonstrated by the fact that for the case of maximum stiffener packing the specific buckling energies are less than those for the case of a shell having twice the original thickness. In order to show trends for various parameter changes several cases of the non-stiffened shells are shown in Figures 9 - 11. Perhaps a more exact representation of the stiffener effects, that is, the use of anisotropic constitutive equations and the associated solution of the resultant coupled governing equations would lead to a more significant contribution of the stiffeners in the specific buckling energy terms.

One important result as determined from observation of several of the post buckled reinforced shells tested and described in Reference (19) is that the addition of stiffeners can influence the wave number of the buckled shell. This can be summarized by use of the following table.

TABLE VII. STIFFENER BUCKLING INFLUENCE

<table>
<tr><th rowspan="2">Loading Factor</th><th colspan="2">Shell Failure Mode</th></tr>
<tr><th>Unstiffened</th><th>Stiffened</th></tr>
<tr><td>L_F</td><td>Collapse</td><td>Circumferential buckling with wave number equal to number of stiffeners in the shell</td></tr>
<tr><td>L_F</td><td colspan="2">Circumferential Buckling with Wave number associated with either number of stiffeners or calculated by Reynold's criteria, whichever yields the higher number.</td></tr>
</table>

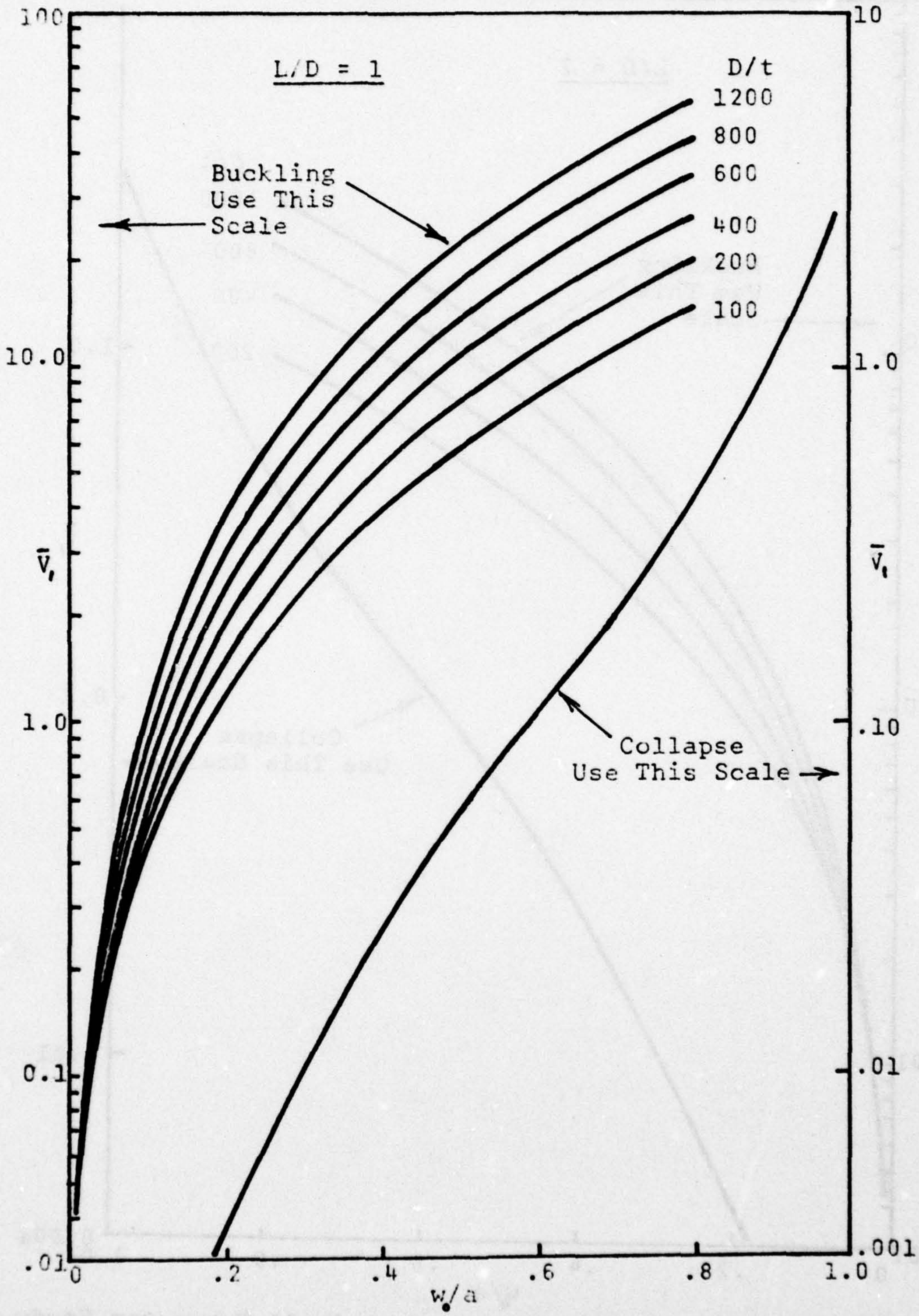


Figure 9. Unstiffened Cylindrical Shell Parameter Study. $\overline{V}_f$ vs w/a. Results of Table IV.

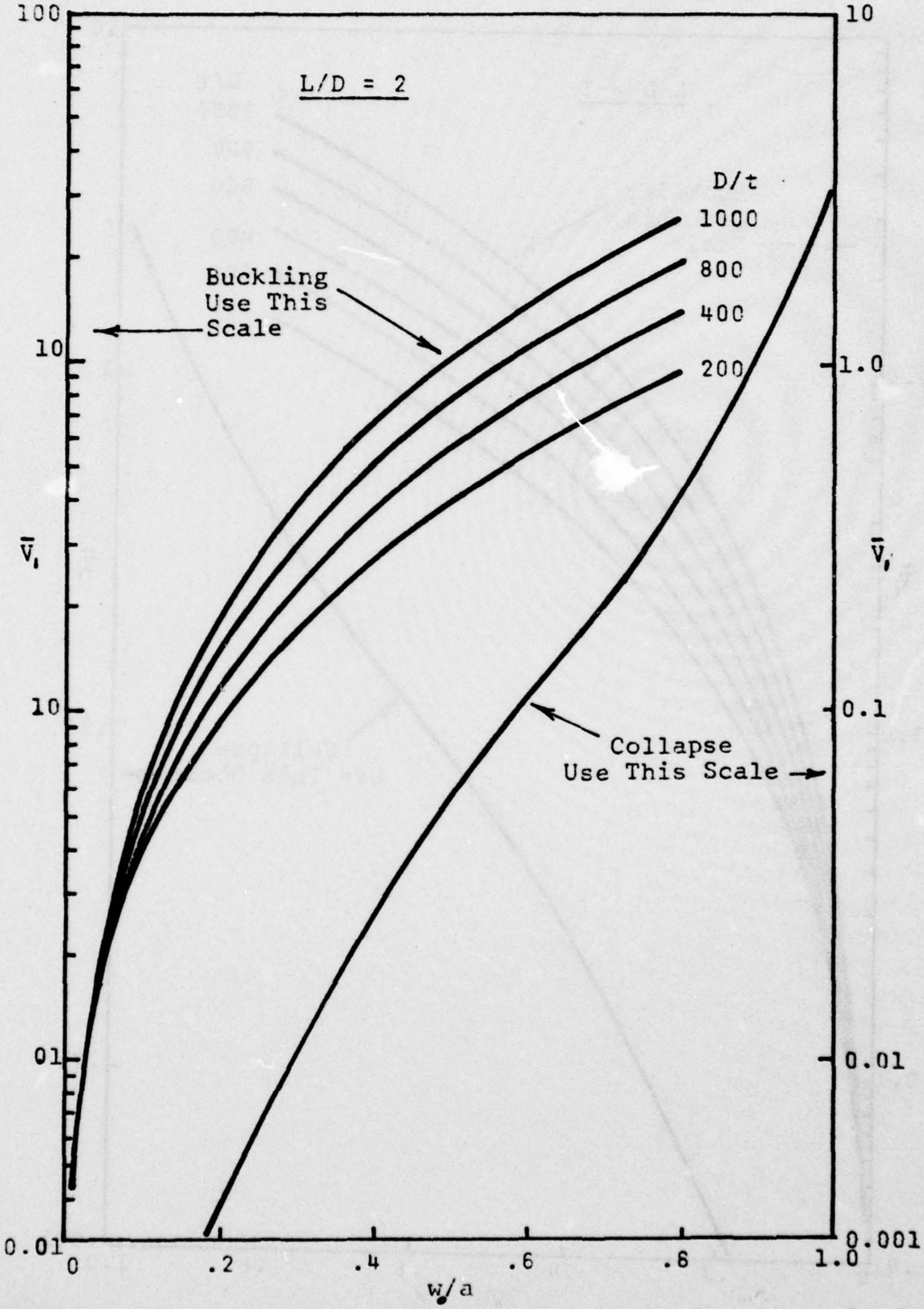


Figure 10. Unstiffened Cylindrical Shell Parameter Study. $\bar{V}_1$ vs w_0/a. Results of Table V.

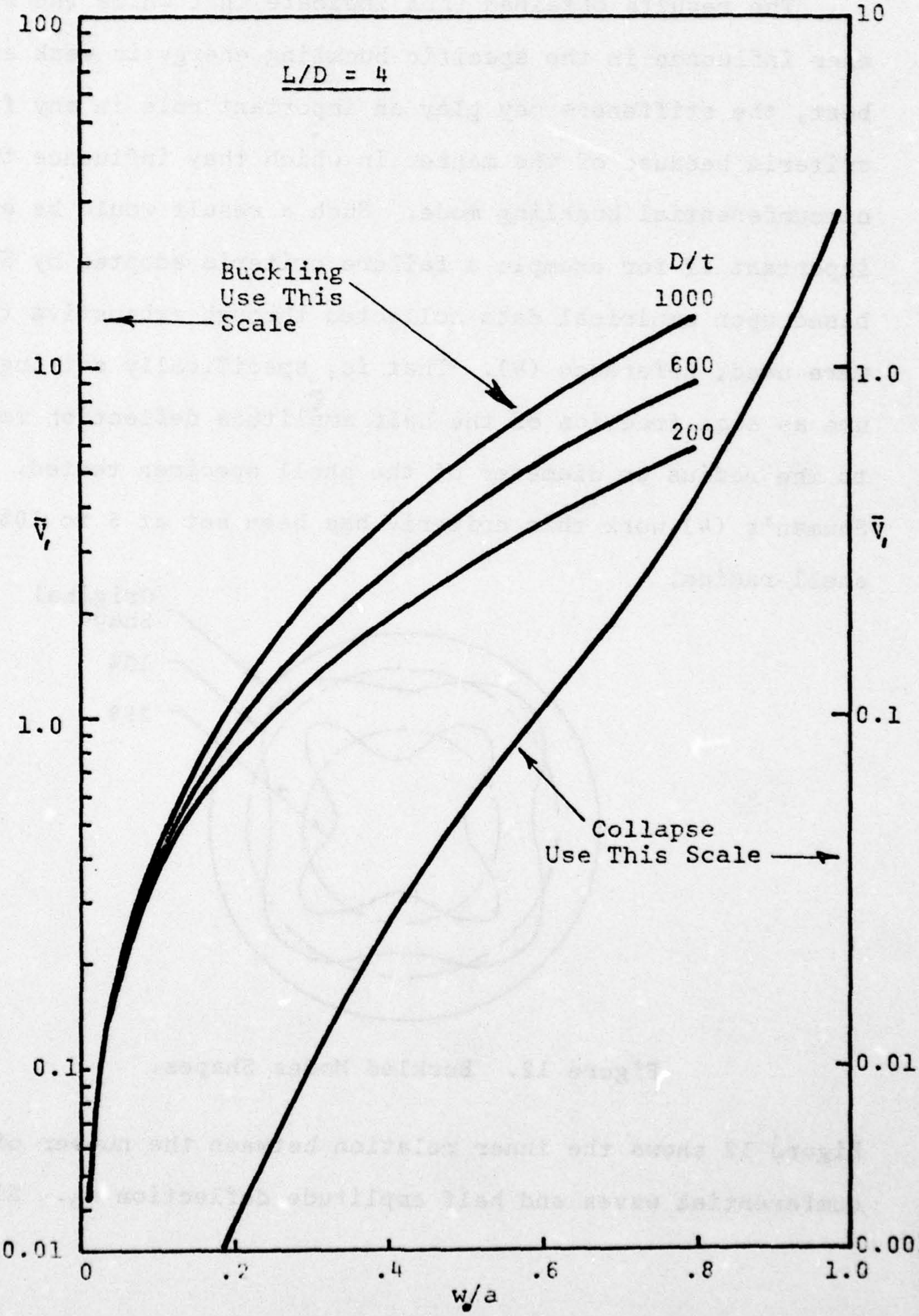


Figure 11. Unstiffened Cylindrical Shell Parameter Study. $\bar{V}_1$ vs w_o/a. Results of Table VI.

The results obtained thus indicate that while the stiffener influence in the specific buckling energy is weak at best, the stiffeners may play an important role in any failure criteria because of the manner in which they influence the circumferential buckling mode. Such a result would be extremely important if for example a failure criteria adopted by Shuman, based upon empirical data collected through exhaustive testing, were used, Reference (4). That is, specifically setting failure as some fraction of the half amplitude deflection relative to the radius or diameter of the shell specimen tested. In Shuman's (4) work this criteria has been set at 5 to 10% of the shell radius.

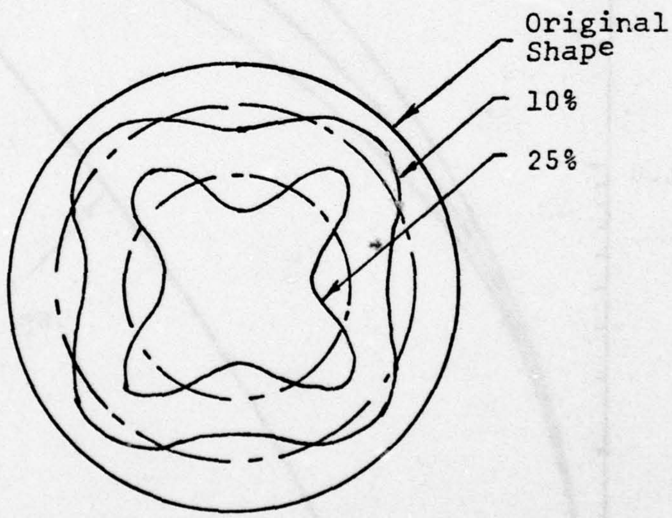


Figure 12. Buckled Modes Shapes.

Figure 12 shows the inner relation between the number of circumferential waves and half amplitude deflection w_o. Since

the change of perimeter during the loading period is negligible the number of circumferential waves as well as w_o will increase with the increase of such pressure or peak impulse whatever criteria is selected as defining loading. Such dependency of the wave number n on the loading and geometrical parameters is not included in either Shuman (4), or Reynolds (20) failure criteria.

SECTION III

DYNAMIC ELASTIC-PLASTIC RESPONSE OF FINITE-LENGTH STIFFENED CYLINDRICAL PANELS TO BLAST LOADS

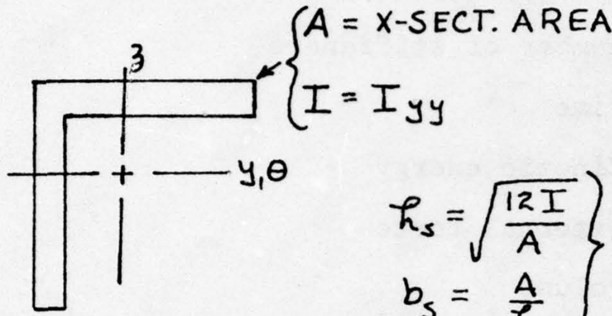
3.1 Introduction

In this section the analytical model (DEPROP) of Mente (17, 18) previously described in Section I has been extended to include axial stiffeners. The selection of this model for modification is based upon its availability and reasonable success in predicting maximum deflections of unstiffened cylindrical shells subjected to intermediate blast loads as reported in Reference (19).

For this particular study the stiffeners have been included only for a single layer with the stiffeners having the same material properties as the panel material. The portions of the DEPROP code (18) associated with multilayer and honeycomb panels have not been modified in this study. The code has been modified to include stiffening for a single layer with both static and dynamic response for either elastic or elastic-plastic stress strain relations.

The stiffeners are assumed to be placed on the center line of the panel thickness. The selection of the stiffener size is determined in the following manner. Assume the stiffener resists forces only by bending about its transverse axis and by tension or compression in the axial direction.

The stiffener is assumed not to buckle. The actual stiffener and the modelled stiffener are shown in Figure 13.



$$h_s = \sqrt{\frac{12I}{A}} \qquad b_s = \frac{A}{h_s}$$

a) actual stiffener   b) modified stiffener

Figure 13. Stiffener Dimensions.

The coordinate system and deflection are shown in Figure 6 of Section I. In many cases the same words or phrases as used in Reference (18) are used in this report. Full credit for the basic model of the unstiffened panel is extended to the authors of Reference (18) and any duplication of sections of Reference (18) in this report are intended for clarity.

3.2 Analytical Development

The governing equations of motion for the stiffened cylindrical panel are obtained from the principle of virtual work for a dynamic structural system which is given by (22)

$$\int_{t_1}^{t_2}\Big[\iiint_V \sigma_{ij}\,\delta\tilde{\varepsilon}_{ij}\,dV + \underline{\sum_{s=1}^{S}\iiint_V \sigma_x\,\delta\varepsilon_x\,dV} - \delta T - \underline{\sum_{s=1}^{S}\delta T} - \iint_A \bar{F}\cdot\delta\bar{r}\,dA\Big]dt = 0\,, \qquad [37]$$

where

σ_{ij}	stress component
ε_{ij}	strain component
S	number of stiffeners
t	time
T	Kinetic energy
$\bar{F}$	external force
V	volume
A	area
$\bar{r}$	deflection
u,v,w	deflection in x,y,z direction and components of general deflection u_i

and

$$\tilde{\varepsilon} = \frac{1}{2}\left(u_{i,j} + u_{j,i} + u_{k,i} + u_{k,j}\right),$$

$$\tilde{\varepsilon}_x = \frac{\partial u}{\partial x} + \frac{1}{2}\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial w}{\partial x}\right)^2\right],$$

$$T = \frac{1}{2}\iiint_V \left(\frac{d\bar{r}}{dt}\right)^2 \rho\, dV = \frac{1}{2}\iiint_V \dot{u}_i \dot{u}_i\, \rho\, dV,$$

$$\sum_{\rho=1}^{S} T = \frac{1}{2}\iiint_V \left[\dot{u}^2 + \dot{w}^2\right]\rho\, dV.$$

The dotted underlined terms represent the contributions of the stiffeners. If it is assumed that $T = T(\dot{u}_1, \dot{u}_2, \dot{u}_3)$, then

$$\delta T = \frac{\partial T}{\partial \dot{u}_i}\,\delta \dot{u}_i \tag{38}$$

with Equation [38] and using integration by parts,

$$\int_{t_1}^{t_2} \delta T\,dt = -\int_{t_1}^{t_2} \frac{d}{dt}\left(\frac{\partial T}{\partial \dot{u}_i}\right)\delta u_i\,dt,$$

$$\sum_{\ell=1}^{S}\int_{t_1}^{t_2} \delta T\,dt = -\sum_{\ell=1}^{S}\int_{t_1}^{t_2}\left[\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{u}}\right)\delta u + \frac{d}{dt}\left(\frac{\partial T}{\partial \dot{w}}\right)\delta w\right]dt. \tag{39}$$

The cylindrical coordinates (x,θ,z) and the axial, tangential and radial displacement components (u,v,w) are shown in Figure 6 on the coordinate surface which is located at the median surface of the panel. It is assumed that $p(x,\theta,t)$ acts on the coordinate surface of the stiffened cylindrical panel. As the panel surface deforms, the elemental pressure force vector also changes as the element surface area of the deformed panel changes. Thus, the vector scalar product of the force and virtual displacement is expressed as

$$F\cdot\delta\bar{r} = p(x,\theta,t)\left(n_x\,\delta r_x + n_y\,\delta r_y + n_z\,\delta r_z\right). \tag{40}$$

By linearizing n_x, n_y, n_z and recasting δr_x, δr_y, δr_z in terms of the virtual displacements δu, δv, δw, the virtual work done by the external forces is given by

$$\iint_A \bar{F}\cdot\delta\bar{r}\,dA = \iint_A p(x,\theta,t)\left(N_u\delta u + N_v\,\delta v + N_w\,\delta w\right)dA \qquad [41]$$

where

$$N_u = -\left(w_x + \overset{\circ}{w}_x\right)$$

$$N_v = -\frac{1}{a}\left(w_\theta + \overset{\circ}{w}_\theta + v\right) \qquad [42]$$

$$N_w = 1 - \frac{1}{a}\left(w + \overset{\circ}{w} - v_\theta\right) + u_x$$

The subscripts on the displacement components denote spatial derivatives and $\overset{\circ}{w}$ denotes the initial radial imperfection in the panel. Assuming $\tilde{\varepsilon}_{ij} = \tilde{\varepsilon}_{ij}(u,v,w)$, $\tilde{\varepsilon}_x = \tilde{\varepsilon}_x(u,w)$, by the chain rule,

$$\delta\tilde{\varepsilon}_{ij} = \frac{\partial\tilde{\varepsilon}_{ij}}{\partial u}\,\delta u + \frac{\partial\tilde{\varepsilon}_{ij}}{\partial v}\,\delta v + \frac{\partial\tilde{\varepsilon}_{ij}}{\partial w}\,\delta w,$$

$$\delta\tilde{\varepsilon}_x = \frac{\partial\tilde{\varepsilon}_x}{\partial u}\,\delta u + \frac{\partial\tilde{\varepsilon}_x}{\partial w}\,\delta w, \qquad [43]$$

and substituting these terms and Equations [41, 42] into Equation [37] the equation of motion becomes

$$\int_{t_1}^{t_2}\Big\{\Big[\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{u}}\right) + \underline{\sum_{a=1}^{S}\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{u}}\right)} + \iiint_V \sigma_{ij}\frac{\partial\tilde{\varepsilon}_{ij}}{\partial u}\,dV$$

$$+ \underline{\sum_{a=1}^{S}\iiint_V \sigma_x\frac{\partial\tilde{\varepsilon}_x}{\partial u}\,dV} - \iint_A p(x,\theta,t)\,N_u\,dA\Big]\delta u$$

$$+\left[\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{v}}\right) + \iiint_V \sigma_{ij}\frac{\partial \tilde{\epsilon}_{ij}}{\partial v}\,dV - \iint_A p(x,\theta,t)\,N_v\,dA\right]\delta v$$

$$+\left[\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{w}}\right) + \sum_{s=1}^{S}\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{w}}\right) + \iiint_V \sigma_{ij}\frac{\partial \tilde{\epsilon}_{ij}}{\partial w}\,dV \qquad [44]$$

$$+\sum_{s=1}^{S}\iiint_V \sigma_x \frac{\partial \tilde{\epsilon}_x}{\partial w}\,dV - \iint_A p(x,\theta,t)\,N_w\,dA\right]\delta w\Bigg\}dt\,.$$

The displacement components are assumed in the following truncated series form

$$u(x,\theta,t) = \sum_{m=1}^{M}\sum_{n=1}^{N} u_{mn}(t)\,\phi_m^u(x)\,\phi_n^u(\theta)\,,$$

$$v(x,\theta,t) = \sum_{m=1}^{M}\sum_{n=1}^{N} v_{mn}(t)\,\phi_m^v(x)\,\phi_n^v(\theta)\,,$$

$$w(x,\theta,t) = \sum_{m=1}^{M}\sum_{n=1}^{N} w_{mn}(t)\,\phi_m^w(x)\,\phi_n^w(\theta)\,, \qquad [45]$$

$$u(x,\theta_s,t) = \sum_{m=1}^{M}\sum_{n=1}^{N} u_{mn}(t)\,\phi_m^u(x)\,\phi_n^u(\theta_s)\,,$$

$$w(x,\theta_s,t) = \sum_{m=1}^{M}\sum_{n=1}^{N} w_{mn}(t)\,\phi_m^w(x)\,\phi_n^w(\theta_s)\,,$$

where $\phi_m(x)$ and $\phi_n(\theta)$ are functions that satisfy the geometric boundary conditions of the stiffened cylindrical panel. The

initial radial imperfection of the stiffened cylindrical panel is represented by

$$\mathring{w}(x,\theta) = \sum_{m=1}^{M}\sum_{n=1}^{N} \Delta_{mn}\, \phi_m^w(x)\, \phi_n^w(\theta) \qquad [46]$$

$$\mathring{w}(x,\theta_s) = \sum_{m=1}^{M}\sum_{n=1}^{N} \Delta_{mn}\, \phi_m^w(x)\, \phi_n^w(\theta_s)$$

where Δ_{mn} are prescribed values based upon assumed deviations from the ideal shape of the stiffened cylindrical panel.

Determining the virtual displacements from Equations [45] and substituting into Equation [44] the 3MN equations of motion may be determined and are given below.

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{u}_{mn}}\right) + \sum_{s=1}^{S}\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{u}_{mn}}\right) + \iiint_V \sigma_{ij}\frac{\partial \hat{\epsilon}_{ij}}{\partial u_{mn}}\,dV$$
$$+ \sum_{s=1}^{S}\iiint_V \sigma_x \frac{\partial \hat{\epsilon}_x}{\partial u_{mn}}\,dV - \iint_A p N_u \frac{\partial u}{\partial u_{mn}}\,dA = 0 \qquad [47a]$$

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{v}_{mn}}\right) + \iiint_V \sigma_{ij}\frac{\partial \hat{\epsilon}_{ij}}{\partial v_{mn}}\,dV - \iint_A p N_v \frac{\partial v}{\partial v_{mn}}\,dA = 0 \qquad [47b]$$

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{w}_{mn}}\right) + \sum_{s=1}^{S}\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{w}_{mn}}\right) + \iiint \sigma_{ij}\frac{\partial \hat{\epsilon}_{ij}}{\partial w_{mn}}$$
$$+ \sum_{s=1}^{S}\iiint_V \sigma_x \frac{\partial \hat{\epsilon}_x}{\partial w_{mn}}\,dV - \iint_A p N_w \frac{\partial w}{\partial w_{mn}}\,dA = 0 \qquad [47c]$$

$$
\text{for} \quad \begin{array}{l} m = 1, 2, \ldots M \\ n = 1, 2, \ldots N \\ s = 1, 2, \ldots S \end{array}
$$

Equations [47] may be simplified by introducing the following notations,

$$
\begin{aligned}
Q^{u}_{mn} &= \rho N_u \frac{\partial u}{\partial u_{mn}}, \\
Q^{v}_{mn} &= \rho N_v \frac{\partial v}{\partial v_{mn}}, \\
Q^{w}_{mn} &= \rho N_w \frac{\partial w}{\partial w_{mn}}.
\end{aligned}
\tag{48}
$$

The kinetic energy of a cylindrical panel is given as

$$
T = \frac{a\rho h}{2} \int_0^{\ell}\int_0^{\theta_0} (\dot{u}^2 + \dot{v}^2 + \dot{w}^2)\, dx\, d\theta. \tag{49}
$$

The strain-displacement relations used in this analysis are based on the following assumptions (18).

(i) the strains are small compared with unity

(ii) the thickness of the shell is small compared with the radius and

(iii) the Kirchhoff-Love hypothesis that straight fibers which are normal to the undeformed coordinate surface remain straight and normal to the deformed coordinate surface, and are not elongated.

The total strain consists of membrane and bending components expressed by the form

$$\tilde{\varepsilon}(x,\theta,z,t) = \varepsilon(x,\theta,t) + z\,K(x,\theta,t). \qquad [50]$$

The membrane elongation and shear strains (ε_{xx}, $\varepsilon_{\theta\theta}$, $\varepsilon_{x\theta}$) on the coordinate surface are expressed in terms of the displacement components and their spatial derivatives,

$$\varepsilon_{xx} = u_x + \frac{1}{2}\left(w_x^2 + u_x^2 + v_x^2\right) + w_x \mathring{w}_x ,$$

$$[51a]$$

$$\tilde{\varepsilon}_x = u_x + \frac{1}{2}\left(w_x^2 + u_x^2\right) + w_x \mathring{w}_x ,$$

$$\varepsilon_{\theta\theta} = \frac{1}{a}\left(v_\theta - w\right) + \frac{1}{2a^2}\left[\left(w_\theta + v\right)^2 + \left(v_\theta - w\right)^2 + u_\theta^2\right] + \frac{1}{a^2} w_\theta \mathring{w}_\theta , \qquad [51b]$$

$$\varepsilon_{x\theta} = v_x + \frac{1}{a} u_\theta + \frac{1}{a} w_x\left(w_\theta + v\right) + \frac{1}{a} v_x\left(v_\theta - w\right)$$

$$[51c]$$

$$+ \frac{1}{a} u_\theta u_x + \frac{1}{a}\left(\mathring{w}_x w_\theta + \mathring{w}_\theta w_x\right).$$

For moderate rotations, the change of curvature quantities (K_{xx}, $K_{\theta\theta}$, $K_{x\theta}$) are given by

$$K_{xx} = w_{xx}\left(1 + \frac{v_\theta}{a} - \frac{w}{a} + u_x\right),$$

$$[52a]$$

$$K_x = w_{xx}\left(1 + u_x\right),$$

$$K_{\theta\theta} = \frac{1}{a} w_{\theta\theta} + \frac{1}{a^2} v_\theta + \frac{1}{a^2}\left(-w + v_\theta\right) + \frac{1}{a} u_x$$

$$+ \frac{1}{a}\left(w_{\theta\theta} + v\right)\left(v_\theta - w\right) + \frac{1}{a^2}\left(w_{\theta\theta} u_x\right) + \frac{1}{a^3}\left(v_\theta - w\right)^2 \qquad [52b]$$

$$+ \frac{1}{a^3}\left(w_\theta + v\right)^2 + \frac{1}{a^3} w_\theta \left(w_\theta + v\right),$$

$$K_{x\theta} = \frac{2}{a} w_{x\theta} + \frac{1}{a} v_x + \frac{2}{a^2} w_{x\theta}\left(v_\theta + a u_x - w\right)$$

$$+ \frac{2}{a^2} w_x \left(w_\theta + v\right), \qquad [52c]$$

The behavior of the stiffened cylindrical panel material is treated as elastic-plastic and the deformation theory of plasticity is used. In the deformation theory of plasticity the total strain is a function of the state of stress and consists of a recoverable elastic component and a nonrecoverable plastic component. It is assumed that the material is incompressible. Furthermore, it is assumed that the material's biaxial state of stress is represented by the bilinear representation shown in Figure 14 in which the strain hardening is defined by the slope E_t. This stress-strain representation employs the effective stress ($\bar{\sigma}$) and effective strain ($\bar{\varepsilon}$) concept, in which the secant modulus (E_S) indicated in Figure 14 is defined by

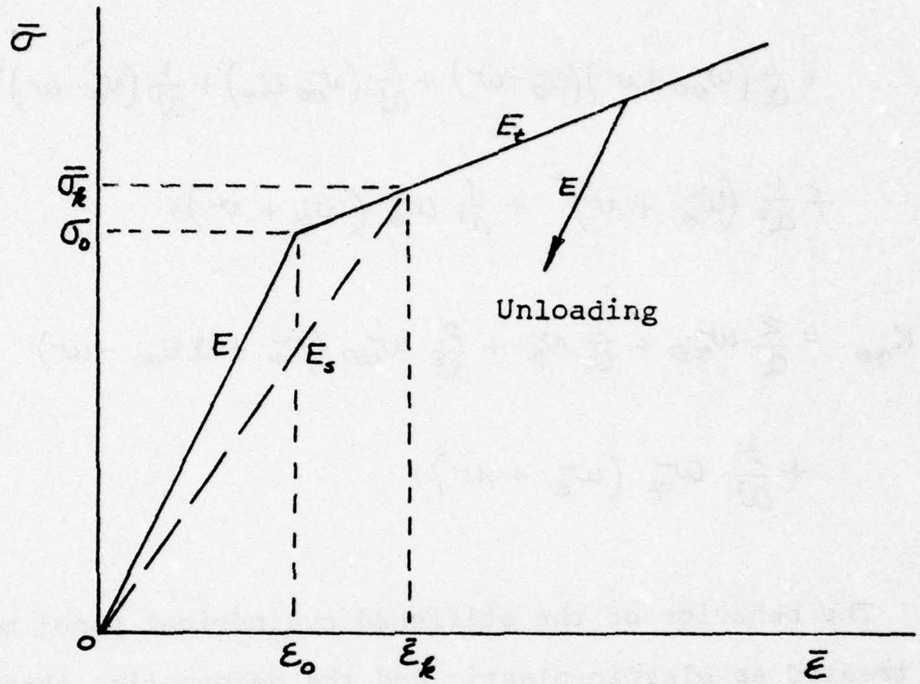


Figure 14. Effective Stress-Strain Bilinear Representation.

$$E_s = \frac{\bar{\sigma}}{\bar{\varepsilon}} = \frac{\sigma_o + E_t(\bar{\varepsilon} - \varepsilon_o)}{\bar{\varepsilon}}, \qquad [53a]$$

and σ_o, ε_o are the yield stress and strain, respectively, from the material's uniaxial bilinear representation. The effective stress and strain, expressed as $\bar{\sigma} = f(\sigma_{ij})$ and $\bar{\varepsilon} = g(\varepsilon_{ij})$ are functions of the total stress and strain components, respectively. For the stiffeners Equation [15a] reduces to

$$E_s = \frac{\bar{\sigma}_x}{\bar{\varepsilon}_x} = \frac{\sigma_o + E_t\,(\bar{\varepsilon}_x - \varepsilon_o)}{\bar{\varepsilon}_x} \;. \qquad [53b]$$

The Hencky stress-strain relations for deformation theory (23) are used in the plastic region and are given in the following form:

$$\tilde{\varepsilon}_{ij} = \frac{1}{E}\left[(1+\nu)\,\sigma_{ij} - \nu\,\sigma_{kk}\,\delta_{ij}\right] + \frac{3}{2}\left(\frac{1}{E_s} - \frac{1}{E}\right)\left(\sigma_{ij} - \frac{1}{3}\,\sigma_{kk}\,\delta_{ij}\right), \qquad [54a]$$

where E is the modulus of elasticity, ν is Poisson's ratio and δ_{ij} is the Kronecker delta. For stiffeners, Equation [53] reduces to

$$\tilde{\varepsilon}_x = \frac{\sigma_x}{E_s} \qquad [54b]$$

For use in Equation [47], the stress-strain relations in Equations [52] are inverted into the form $\sigma_{ij} = f(\tilde{\varepsilon}_{ij})$ for the case of plane stress (i.e., $\sigma_{zz} = \sigma_{\theta z} = \sigma_{xz} = 0$) and are given by

$$\sigma_{ij} = \frac{E_s}{1-\nu_s^2}\left[(1-\nu_s)\,\tilde{\varepsilon}_{ij} + \nu_s\,\varepsilon_{kk}\,\delta_{ij}\right] \quad , (i, j, k = 1, 2), \qquad [55a]$$

where

$$\nu_s = \frac{1}{2} - \frac{E_s}{E}\left(\frac{1}{2} - \nu\right),$$

$$\tilde{\varepsilon}_{12} = \frac{1}{2}\tilde{\varepsilon}_{x\theta} \, , \; \tilde{\varepsilon}_{11} = \tilde{\varepsilon}_{xx} \, , \; \tilde{\varepsilon}_{22} = \tilde{\varepsilon}_{\theta\theta} \, .$$

For stiffeners the assumption is made that,

$$\underline{\sigma_x = E_s \tilde{\varepsilon}_x \, .} \qquad [55b]$$

The initiation of yielding for a biaxial state of stress is based on the Mises-Hencky yield criterion and given as

$$\bar{\sigma} = (\sigma_{11}^{2} + \sigma_{22}^{2} - \sigma_{11}\sigma_{22} + 3\sigma_{12}^{2})^{\frac{1}{2}} \qquad [56]$$

where $\bar{\sigma}$ is the equivalent or effective stress and

$$\sigma_{11} = \sigma_{xx} \, , \; \sigma_{22} = \sigma_{\theta\theta} \, , \; \sigma_{12} = \sigma_{x\theta} \, .$$

A kinematic hardening model is employed in conjunction with the Mises-Hencky yield surface which accounts for the Bauchinger effect when yielding occurs again due to the strain reversals during unloading. It is assumed that during plastic deformation the yield surface translates as a rigid body in stress space. This type of kinematic hardening model, as used in this report, is shown in Figure 15. The change in total stress components from position (i) to position (f) as indicated in Figure 15 are defined by $\tilde{\alpha}_{ij}$ and, the corresponding change in the total strain components are defined by $\tilde{\beta}_{ij}$ so that

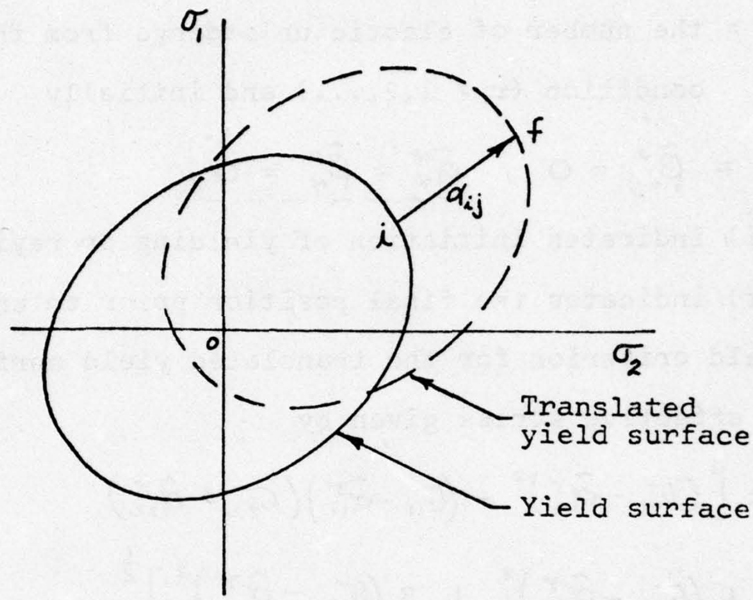


Figure 15. Kinematic Hardening Model

$$\tilde{\alpha}_{ij}^{r} = \tilde{\alpha}_{ij}^{r-1} + \tilde{\sigma}_{ij(f)}^{r-1} - \tilde{\sigma}_{ij(i)}^{r-1} ,$$

$$\tilde{\beta}_{ij}^{r} = \tilde{\beta}_{ij}^{r-1} + \tilde{\varepsilon}_{ij(f)}^{r-1} - \tilde{\varepsilon}_{ij(i)}^{r-1} , \qquad [57a]$$

and for stiffeners the expressions are

$$\tilde{\alpha}_{x}^{r} = \tilde{\alpha}_{x}^{r-1} + \tilde{\sigma}_{x(f)}^{r-1} - \tilde{\sigma}_{x(i)}^{r-1} ,$$

$$\tilde{\beta}_{x}^{r} = \tilde{\beta}_{x}^{r-1} + \tilde{\varepsilon}_{x(f)}^{r-1} - \tilde{\varepsilon}_{x(i)}^{r-1} , \qquad [57b]$$

where

r = the number of elastic unloadings from the yielded condition (r = 1,2,...) and initially

$$\tilde{\alpha}^{o}_{ij} = \tilde{\beta}^{o}_{ij} = 0 \,, \quad \tilde{\alpha}^{o}_{\gamma} = \tilde{\beta}^{o}_{\gamma} = 0 \,,$$

(i) indicates initiation of yielding or reyielding,

(f) indicates the final position prior to unloading.

The yield criterion for the translated yield surface is based on the effective stress given by

$$\bar{\sigma} = \Big[(\sigma_{11} - \tilde{\alpha}^{r}_{11})^2 - (\sigma_{11} - \tilde{\alpha}^{r}_{11})(\sigma_{22} - \tilde{\alpha}^{r}_{22}) + (\sigma_{22} - \tilde{\alpha}^{r}_{22})^2 + 3(\sigma_{12} - \tilde{\alpha}^{r}_{12})^2 \Big]^{\frac{1}{2}} \qquad [58]$$

$$\bar{\sigma}_{\gamma} = (\sigma_{\gamma} - \tilde{\alpha}^{r}_{\gamma}) \,,$$

and the effective strain is given by

$$\bar{\varepsilon} = \Big\langle \frac{1}{(1-\nu_s^2)^2} \Big\{ (1-\nu_s+\nu_s^2)\Big[(\hat{\varepsilon}_{11} - \tilde{\beta}^{r}_{11})^2 + (\hat{\varepsilon}_{22} - \tilde{\beta}^{r}_{22})^2\Big] - (1-4\nu_s+\nu_s^2)(\hat{\varepsilon}_{11} - \tilde{\beta}^{r}_{11})(\varepsilon_{22} - \tilde{\beta}^{r}_{22}) \Big\} + \frac{3}{(1+\nu_s)^2}(\hat{\varepsilon}_{12} - \tilde{\beta}^{r}_{12}) \Big\rangle^{\frac{1}{2}} , \qquad [59]$$

$$\bar{\varepsilon}_{\gamma} = (\varepsilon_{\gamma} - \beta^{r}_{\gamma}) \,.$$

The general stress-strain relations based on the form of Equation [55] is given by

$$\sigma_{ij} = \tilde{\alpha}^{r}_{ij} + \frac{E_s}{1-\nu_s^2}\Big[(1-\nu_s)(\hat{\varepsilon}_{ij} - \tilde{\beta}^{r}_{ij}) + \nu_s(\hat{\varepsilon}_{kk} - \tilde{\beta}^{r}_{kk})\,\delta_{ij}\Big] , \qquad [60a]$$

$$(i, j, k = 1, 2) \,,$$

and for the stiffeners

$$\sigma_x = \tilde{\alpha}_x^r + E_s\left(\bar{\varepsilon}_x - \tilde{\beta}_x^r\right) \qquad [60b]$$

where

(a) initial elastic loading $E_s = E$, $\tilde{\alpha}_{ij}^r = \tilde{\beta}_{ij}^r = 0$,

(b) initial plastic loading $E_s = E_s$, $\tilde{\alpha}_{ij}^r = \tilde{\beta}_{ij}^r = 0$,

(c) qth elastic unloading $E_s = E$, $\tilde{\alpha}_{ij}^r = \tilde{\alpha}_{ij}^q$, $\tilde{\beta}_{ij}^r = \tilde{\beta}_{ij}^q$,

(d) qth reyielding $E_s = E_s$, $\tilde{\alpha}_{ij}^r = \tilde{\alpha}_{ij}^q$, $\tilde{\beta}_{ij}^r = \tilde{\beta}_{ij}^q$.

The boundary conditions on the stiffeners are assumed to be the same as those imposed on the panel which are described in Reference (18) and established as input data.

The governing equations of motion (47) for elastic-plastic deformation are developed further by performing the indicated spatial integrations. For convenience the dimensionless quantities

$$W = \frac{w}{a}, \; V = \frac{v}{a}, \; U = \frac{u}{a}, \; \dot{W} = \frac{\dot{w}}{a}, \; L = \frac{l}{\pi a}, \; J = \frac{\pi}{\theta_0}$$

$$R = \frac{a}{h}, \; \bar{K} = Ka, \; \gamma = \frac{\pi x}{l}, \; \beta = \frac{\pi\theta}{\theta_0}, \; \theta_p = \frac{s\theta_0}{S},$$

are introduced into the formulations. In Equation [49] θ_o must be given in radians, however in the input data θ_o is given in degrees. Care must be exercised when using θ_o by itself, such

as in J above and in the second term of Equation [59a] below, it must be converted to radians for computational purposes. With this notation and the spatial integration for the kinetic energy in Equation [49] performed analytically, the governing equations of motions for clamped opposite edges are given as

$$
\begin{aligned}
&2\rho l^2\left\{\ddot{U}_{mn} + \frac{b_s h_s}{a h \Theta_0}\sum_{\rho=1}^{S}\phi_n^u(\beta_\rho)\sum_{q=1}^{N}\ddot{U}_{mq}\,\phi_q^u(\beta_\rho)\right\} \\
&+\frac{2L^2}{h}\left\{\int_0^{\pi}\int_0^{\pi}\int_{-\frac{h}{2}}^{\frac{h}{2}}\sigma_{ij}\frac{\partial\tilde{\varepsilon}_{ij}}{\partial U_{mn}}\,d\gamma\, d\beta\, dz\right. \\
&\left.+\frac{b_s\pi}{a\Theta_0}\int_0^{\pi}\int_{-\frac{h_\rho}{2}}^{\frac{h_\rho}{2}}\sum_{\rho=1}^{S}\sigma_\gamma\frac{\partial\tilde{\varepsilon}_\gamma}{\partial U_{mn}}\,d\gamma\, dz\right\} \\
&-\int_0^{\pi}\int_0^{\pi}\tilde{Q}_u\, d\gamma\, d\beta = 0
\end{aligned}
\qquad [61a]
$$

$$
\begin{aligned}
&2\rho l^2\ddot{V}_{mn} + \frac{2L^2}{h}\int_0^{\pi}\int_0^{\pi}\int_{-\frac{h}{2}}^{\frac{h}{2}}\sigma_{ij}\frac{\partial\tilde{\varepsilon}_{ij}}{\partial V_{mn}}\,d\gamma\, d\beta\, dz \\
&-\int_0^{\pi}\int_0^{\pi}\tilde{Q}_v\, d\gamma\, d\beta = 0
\end{aligned}
\qquad [61b]
$$

$$
\begin{aligned}
&2\rho l^2 \left\{ \ddot{W}_{mn} + \frac{b_s h_s \pi}{a h \Theta_0} \sum_{r=1}^{S} \phi_n^w(\beta_r) \sum_{q=1}^{N} \ddot{W}_{mq} \phi_q^w(\beta_r) \right\} \\
&+ \frac{2L^2}{h} \left\{ \int_0^{\pi}\int_0^{\pi}\int_{-\frac{h}{2}}^{\frac{h}{2}} \sigma_{ij} \frac{\partial \hat{\varepsilon}_{ij}}{\partial W_{mn}} \, d\gamma \, d\beta \, dz \right. \\
&+ \frac{b_s \pi}{a \Theta_0} \int_0^{\pi}\int_{-\frac{h_r}{2}}^{\frac{h_r}{2}} \sum_{r=1}^{S} \sigma_x \frac{\partial \tilde{\varepsilon}_x}{\partial W_{mn}} \, d\gamma \, dz \\
&- \int_0^{\pi}\int_0^{\pi} \tilde{Q}_W \, d\gamma \, d\beta = 0 .
\end{aligned}
\qquad [61c]
$$

$(m = 1,2,\ldots M)$,

$(n = 1,2,\ldots N)$,

where

$$
\begin{aligned}
\tilde{Q}_U &= -2LR\rho\left(W_\gamma + \mathring{W}_\gamma\right)\frac{\partial U}{\partial U_{mn}} , \\
\tilde{Q}_V &= -2L^2R\rho\left(JW_\beta + J\mathring{W}_\beta + V\right)\frac{\partial V}{\partial V_{mn}} , \\
\tilde{Q}_W &= -2L^2R\rho\left(1 - W - \mathring{W} + JV_\beta + \frac{U_\gamma}{L}\right)\frac{\partial W}{\partial W_{mn}} .
\end{aligned}
\qquad [62]
$$

The spatial integrations described by Equations [61] are to be accomplished numerically. For integration through the thickness of the panel in the z direction, it is convenient to separate the integrand into parts which either are or are

not explicitly dependent on the z variable, that is, those variables involving membrane strains and bending strains. The total strain quantities $\tilde{\varepsilon}_{ij}$ consist of the membrane and bending components given by

$$\tilde{\varepsilon}_{ij} = \varepsilon_{ij} + z K_{ij} \qquad [63]$$

Therefore, the integrand can be given by

$$f^{m} + z f^{b},$$

where

$$f^{mu} = \sigma_{xx} \frac{\partial \epsilon_{xx}}{\partial U_{mn}} + \sigma_{\theta\theta} \frac{\partial \epsilon_{xx}}{\partial U_{mn}} + \sigma_{x\theta} \frac{\partial \varepsilon_{x\theta}}{\partial U_{mn}}, \qquad [64a]$$

$$f^{bu} = \sigma_{xx} \frac{\partial K_{xx}}{\partial U_{mn}} + \sigma_{\theta\theta} \frac{\partial K_{\theta\theta}}{\partial U_{mn}} + \sigma_{x\theta} \frac{\partial K_{x\theta}}{\partial U_{mn}}, \qquad [64b]$$

for cylinders and

$$\underline{f_{s}^{mu} = \sigma_{x} \frac{\partial \epsilon_{xx}}{\partial U_{mn}}}, \qquad [65a]$$

$$\underline{f_{s}^{bu} = \sigma_{x} \frac{\partial K_{xx}}{\partial U_{mn}}}, \qquad [65b]$$

for stiffeners. Although Equations [64], [65] are given in terms U_{mn}, similar expressions can be obtained by replacing U_{mn} with V_{mn} and W_{mn}; U_{mn} with W_{mn} respectively.

The Legendre-Gauss quadrature formula (18) was chosen for the numerical integration in the z direction where $\bar{L}$ is the number of points selected through the thickness of the panel. For integration in the γ and β directions Simpson's quadrature formula was used. The number of spatial points selected in the γ and β directions are given by $\bar{M}$ and $\bar{N}$, respectively, where $\bar{M}$ and $\bar{N}$ must be odd numbers. By performing the indicated numerical integrations, Equations [61] take the following form:

$$
\begin{aligned}
& k_\gamma k_\beta \rho \ell^2 \left\{ \ddot{U}_{mn} + \frac{b_s h_s \pi}{a h \theta_0} \sum_{a=1}^{S} \phi_m^u(\beta_a) \sum_{g=1}^{N} \ddot{U}_{mg}\, \phi_g^u(\beta_a) \right\} \\
& \frac{\pi^2}{9(\bar{M}-1)(\bar{N}-1)} \sum_{j=1}^{\bar{M}} \sum_{k=1}^{\bar{N}} H_j H_k \left\{ L^2 \sum_{i=1}^{\bar{L}} H_i\, f_i^{m_U}(\gamma_j, \beta_k) \right. \\
& \left. + \frac{1}{2R} f_i^{b_U}(\gamma_i, \beta_k) - \tilde{Q}_U(\gamma_j, \beta_k) \right. \qquad [66a] \\
& + \frac{\pi}{3(\bar{M}-1)} \sum_{j=1}^{\bar{M}} H_j \left\{ \frac{b_s \pi}{a \theta_0} L^2 \sum_{a=1}^{S} \sum_{i=1}^{\bar{L}} H_i \left[f_{a_i}^{m_U}(\gamma_j, \beta_a) \right. \right. \\
& \left. \left. + \frac{1}{2R} \xi_i\, f_{a_i}^{b_U}(\gamma_j, \beta_a) \right] \right\} = 0 ,
\end{aligned}
$$

$$k_\gamma k_\beta \rho \ell^2 \ddot{V}_{mn} + \frac{\pi^2}{9(\bar{M}-1)(\bar{N}-1)} \sum_{j=1}^{\bar{M}} \sum_{k=1}^{\bar{N}} H_j H_k \Big\{ L^2 \sum_{i=1}^{\bar{L}} H_i \Big[f_i^{m_v}(\gamma_j, \beta_k)$$

$$+ \frac{1}{2R} \xi_i f_i^{b_v}(\gamma_j, \beta_k) - \tilde{Q}_v(\gamma_j, \beta_k) \Big\} = 0, \qquad [66b]$$

$$k_\gamma k_\beta \rho \ell^2 \Big\{ \ddot{W}_{mn} + \underline{\frac{b_s h_s \pi}{a h \theta_0} \sum_{\rho=1}^{S} \phi_n^w(\beta_\rho) \sum_{q=1}^{N} \ddot{W}_{mq} \phi_q^w(\beta_\rho)} \Big\}$$

$$+ \frac{\pi^2}{9(\bar{M}-1)(\bar{N}-1)} \sum_{j=1}^{\bar{M}} \sum_{k=1}^{\bar{N}} H_j H_k \Big\{ L^2 \sum_{i=1}^{\bar{L}} H_i \Big[f_i^{m_w}(\gamma_j, \beta_k)$$

$$+ \frac{1}{2R} f_i^{b_w}(\gamma_j, \beta_k) - \tilde{Q}_w(\gamma_i, \beta_k) \Big\}$$

$$\underline{+ \frac{\pi}{3(\bar{M}-1)} \sum_{j=1}^{\bar{M}} H_j \Big\{ \frac{b_s \pi}{a \theta_0} L^2 \sum_{\rho=1}^{S} \sum_{i=1}^{\bar{L}} H_i \Big[f_{\rho i}^{m_w}(\gamma_j, \beta_\rho)} \qquad [66c]$$

$$\underline{+ \frac{1}{2R} \xi_i f_{\rho i}^{b_w}(\gamma_j, \beta_\rho)} \Big\} = 0,$$

$$(m = 1, 2, \ldots M), \; (n = 1, 2, \ldots N).$$

where for the w equation

$$k_\gamma = k_\beta = \sqrt{2} \qquad \text{for c-c, c-s} \quad \text{opposite boundaries}$$

$$k_\gamma = k_\beta = 1/\sqrt{2} \qquad \text{for s-s} \quad \text{opposite boundaries}$$

and for u and v equations

$$k_\gamma = k_\beta = 1/\sqrt{2},$$

and ξ_i are the zeros of the Legendre polynomial $P_{\bar{L}}(\xi)$.

$$H_i = \frac{2(1-\xi_i^2)}{(\bar{L}+1)^2[P_{\bar{L}+1}(\xi_i)]^2}, \quad z_i = \frac{h}{2}\xi_i,$$

$$H_{j \text{ or } k} = 4 \quad \text{(j,k = even)}$$

$$= 2 \quad (\text{j,k = odd, except for } j=1,\bar{M} \text{ or } k=1,\bar{N})$$

$$= 1 \quad (j_1=1,\bar{M} \text{ and } k=1,\bar{N})$$

$$\gamma_j = \left(\frac{j-1}{\bar{M}-1}\right)\pi, \quad \beta_k = \left(\frac{k-1}{\bar{N}-1}\right)\pi.$$

When symmetry is present in both the γ and β direction, only one quarter of the panel need be considered (18).

The second order differential given by Equations [66] are solved numerically in time and the time wise steps are based on the central difference equation

$$X_{k+1} = \ddot{X}_k(\Delta t)^2 + 2X_k - X_{k-1} \qquad [67]$$

where X represent the normalized time dependent displacement coefficient U_{mn}, V_{mn}, W_{mn}, Δt is the time increment and k denotes the current time step. The Δt required for calculations

with stiffeners included is independent of θ and for n greater than m the Δt calculated by the program for a given panel thickness will suffice for the case with stiffeners. If instability problems arise the time step should be reduced by approximately the ratio of panel thickness to stringer height.

The reaction forces are calculated in the same manner as described in Reference (18) and the stiffener reaction forces are simply added to the shell reaction forces at the stiffener locations.

3.3 Panel Loading Program Options

Four transient pressure loading options (identical to those of DEPROP (18)) are incorporated into the DEPROSP program to describe the pressure function $p(x,\theta,t)$ which is designated as positive in the negative z-direction. The first loading option is an analytical representation of the transient pressure on a flat panel generated from the detonation of a projectile fired into an adjacent fluid medium. The second option provides a method for a more arbitrary pressure loading through spatial and temporal discretization of the pressure field. The third option contains a simple uniform pressure distribution over the panel with a combination of exponential and triangular time decay behind a sharp-edged blast front. The fourth option is also for a uniform pressure loading, but with an arbitrary temporal discretization. These loading options are discussed briefly in the following paragraphs.

3.3.1 Loading Option 1

This option describes a transient pressure loading $p(x,y,t)$ generated from test data obtained on a flat plate subjected to the pressure loading from the detonation of a projectile fired into an adjacent fluid medium. As shown in Figure 16 the trajectory of the projectile is defined by the obliquity angle ϕ and the detonation position is a distance Z from the flat panel. This pressure model is based on the assumptions that the shock wave shape is spherical, shock velocity is constant at 58,800 inch/second and the pressure pulse is triangular with a duration of t_d. If it is assumed that time (sec) initiates when the blast wave reaches the center of the panel, the time of arrival of the blast wave at an arbitrary point (x,y) on the panel is given by

$$t_a = \frac{R - A}{58800} \qquad [68]$$

where R is the distance from the detonation point given by

$$(x^2 + y^2 + Z^2)^{1/2} \quad .$$

The normal pressure $p(x,y,t)$ at this arbitrary point on the panel is described as:

$$p(x,y,t) = 0 \quad , \quad t < t_a$$

$$p(x,y,t) = 0 \quad , \quad t > t_a + t_d \qquad [69]$$

$$p(x,y,t) = (p_m \cos\alpha)\left(1 + \frac{t_a - t}{t_d}\right) \; , \quad t_a \le t \le t_a + t_d \, ,$$

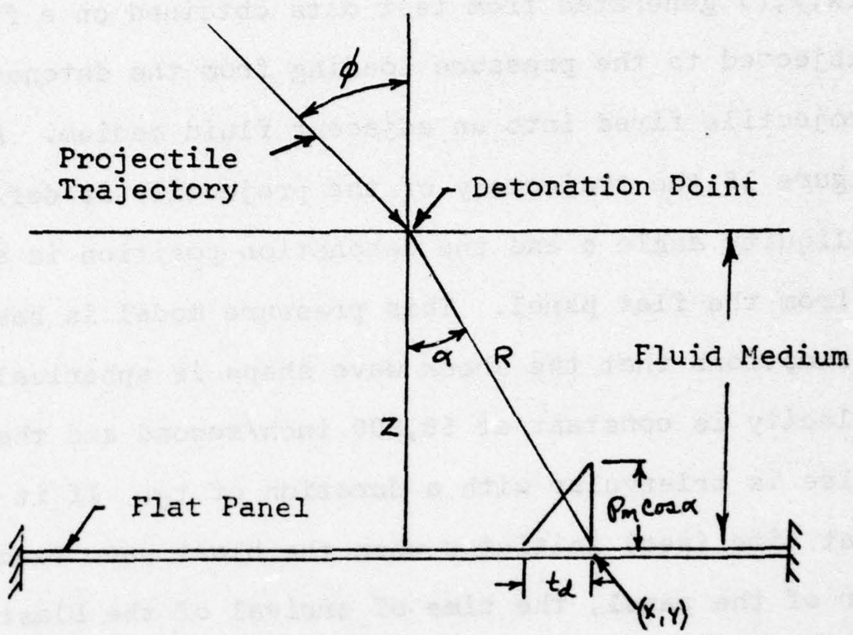


Figure 16. Loading Geometry.

where

$$P_m = 484.95 \left(t + \frac{Z}{58800}\right)^{-.29} \qquad \text{(psi)}$$

$$\cos\alpha = Z/R$$

$$t_d = A - B\left(t + \frac{Z}{58800}\right) \qquad \text{(sec)}$$

for $\phi = 0°$: $A = 87 \times 10^{-6}$, $B = .0686$

$= 30°$: $A = 90 \times 10^{-6}$, $B = .1127$

$= 60°$: $A = 84 \times 10^{-6}$, $B = .1275$.

3.3.2 Loading Option 2

A non-uniform load can be applied to either a curved or flat panel by specifying a discrete pressure-time history for an array of selected points covering the surface of the panel. The spatial array of points need not coincide with the integration grid point (determined by $\overline{M}$, $\overline{N}$), but must be a regular grid in the sense that all points remain in rows and columns in the x-θ plane, although the spacing between rows (and columns) need not be constant. The spatial grid should also span the entire portion of the panel analyzed or the program will be forced to linearly extrapolate pressures toward the edges.

The timewise variation is specified at a set of evenly spaced times - the spacing, $\Delta\bar{t}$, is the same for all points. However, the time history of each point does not begin until time corresponding to a unique delay time has been reached. This delay time corresponds to the time of shock arrival and is specified on input for each grid point. It is important that the first point in the array to be engulfed have a delay time equal to zero.

Pressures at intermediate times and interior spatial points are determined by linear interpolation. No attempt has been made to estimate shock arrival at interior points, thus, the shock wave will tend to be smeared unless a great

number of grid points are used. For times beyond the last time allowed for in the loading, a pressure equal to the last value specified at that grid point is used.

3.3.3 Loading Option 3

The third load option assumes a uniform distribution over the surface of the panel, with simultaneous engulfment. A single pressure-time history describes the entire loading sequence. The pressure loading is an analytical representation of a combination of triangular and exponential decay, as indicated in Figure 17. The pressures in the three regions indicated in Figure 17 are given in analytical form as follows:

$$p_I(t) = p_1 \left(1 - \frac{t}{t_1}\right) \qquad (t < t')$$

$$p_{II}(t) = p_o \left(1 - \frac{t}{t_o}\right)^n e^{-\frac{at}{t_o}} \qquad (t' \leq t < t_o) \qquad [70]$$

$$p_{III}(t) = 0 \qquad (t \geq t_o) .$$

It should be noted that the second function is used for time greater than or equal to t'; hence, by specifying t' = 0 the special loading cases indicated in Table VIII (step, triangular, impulse, exponential) can easily be generated, where I is the impulse and Δt is the integration time interval.

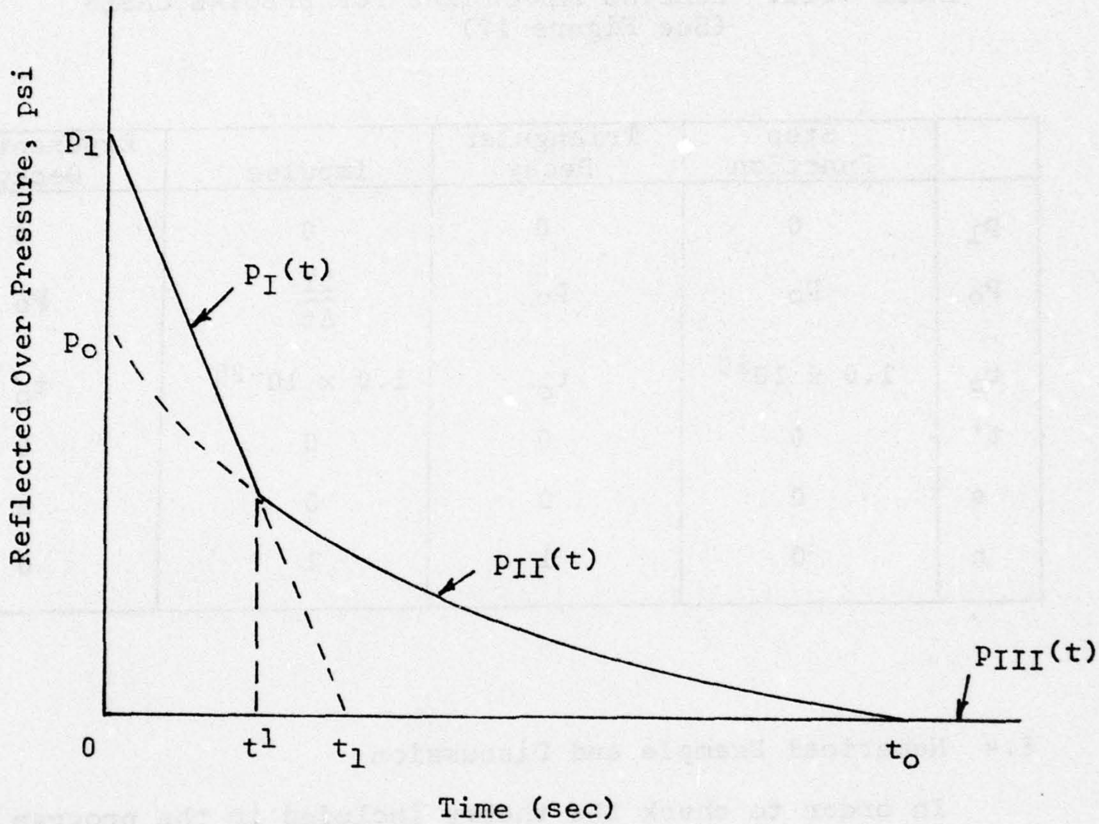


Figure 17. Analytical Pressure Time History.
(See Table VIII)

3.3.4 Loading Option 4

Like the previous option, loading option 4 is appropriate for uniformly applied loads without consideration of engulfment. With this option, discrete values of pressures are specified at a set of times, beginning at zero. For other times, linear interpolation is used, except after the last time in the table, when a pressure equal to the last value is assumed.

TABLE VIII. LOADING PARAMETERS FOR SPECIAL CASES (See Figure 17)

	Step Function	Triangular Decay	Impulse	Exponential Decay
p_1	0	0	0	0
p_o	p_o	p_o	$\frac{2I}{\Delta t}$	p_o
t_o	1.0×10^{10}	t_o	1.0×10^{-20}	t_o
t'	0	0	0	0
a	0	0	0	a
n	0	1	1	0

3.4 Numerical Example and Discussion

In order to check the theory included in the program and study the effect of stiffening three cases were run using the DEPROSP program. A schematic of the cylindrical shell and the stiffener locations are shown in Figure 18. The kind of material and pressure loading was the same for all three cases and are given in Figure 18. The same basic 180° cylindrical shell axially stiffened at the 45°, 90° and 135° positions was used for runs with 1) zero stiffeners, 2) stiffeners with height equal to shell thickness and 3) a stiffener height of .75 in (1.91 cm). The stiffener width for cases 2 and 3 was .121 in (.307 cm) which for

the latter case gives an approximate bending stiffness of a .75x.75x.063 in (1.91x1.91x.16 cm) equal leg angle. The pressure loading, simulating a plane wave impinging on a cylinder (24), was assumed constant in the longitudinal direction and variations with θ and time are shown in Figure 18. The odd mode numbers n between 1 and 13 inclusive were used to define the deflection circumferentially and the fundamental mode of $m = 1$ was used for the axial direction.

The results of these three cases in general show that the effect of the stiffener is minimal when compared to the shell without stiffeners. This is in agreement with the results of Section 2.2.3 which showed the same general results for the modified Greenspon solution of a 360° cylindrical shell.

For the DEPROSP calculation of the cylindrical panel shown in Figure 18, the difference between calculated deflections for the stiffened and unstiffened case is so small that if presented in graphical form they would be indistinguishable. However, the results of the stiffened case are shown in Figure 19 along with deformed shape of a similiar cylinder tested under the loading conditions specified in Figure 18. The calculated deflection shape of Figure 19 shows no local influence of the stiffeners, whereas the local influence of the stiffeners is quite discernible for the experimental curve.

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STUDIES ON THE FAILURE OF STIFFENED CYLINDRICAL SHELLS SUBJECTE--ETC(U)

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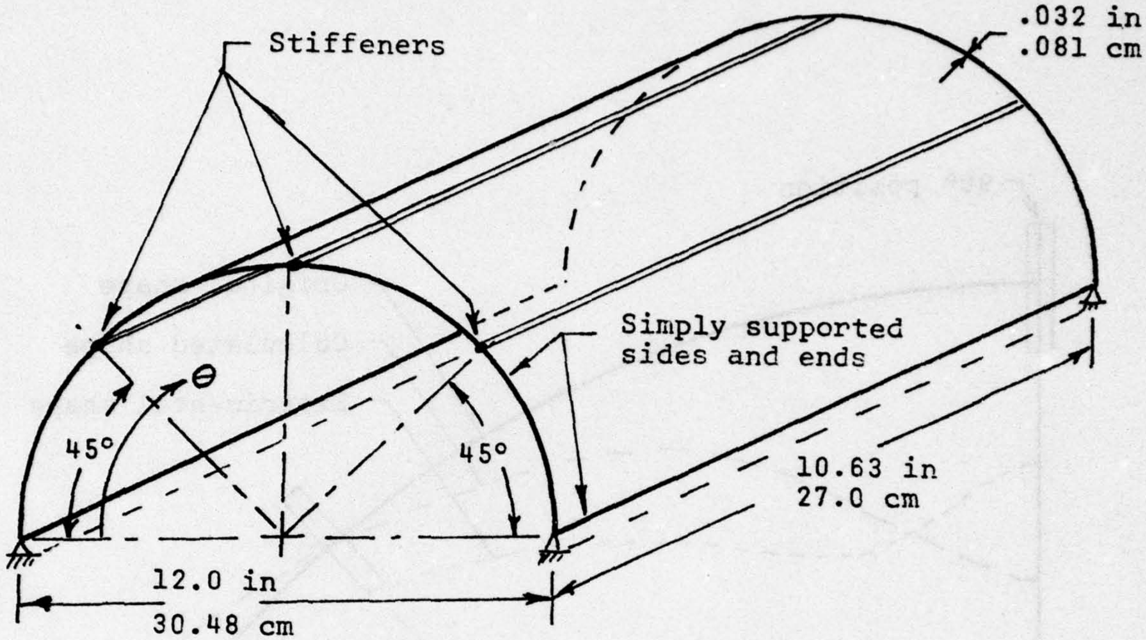
The influence of stiffeners on the stress and strain distributions of the unstiffened panel studied (Figure 18) is also minimal with only slight reduction in stress and strain. Redistribution of stresses and strains occur but the overall changes are small.



Material: 6061-T6 Aluminum	
Yield stress	36,000 psi
Elastic modulus	9.9×10^6 psi
Work hardening slope	60,000 psi
Density	0.1 lb/in^3
Poisson's ratio	0.3

Pressure Loading

The distributed load in psi and time in millisec are listed below for the given angle.

θ				
0°	22°.5	45°	67°.5	90°
280 - .0	260 - .07	170 - .09	106 - .12	66 - .13
175 - .14	154 - .21	104 - .23	59 - .26	29 - .27
102 - .28	86 - .35	60 - .37	31 - .40	12 - .41
53 - .42	42 - .49	30 - .51	14 - .54	5 - .55
21 - .66	16 - .73	12 - .75	5 - .75	1 - .79
0 - .70	0 - .77	0 - .79	0 - .82	0 - .83

Figure 18. Schematic of Shell, Material Properties and Pressure Loading for Numerical Example.

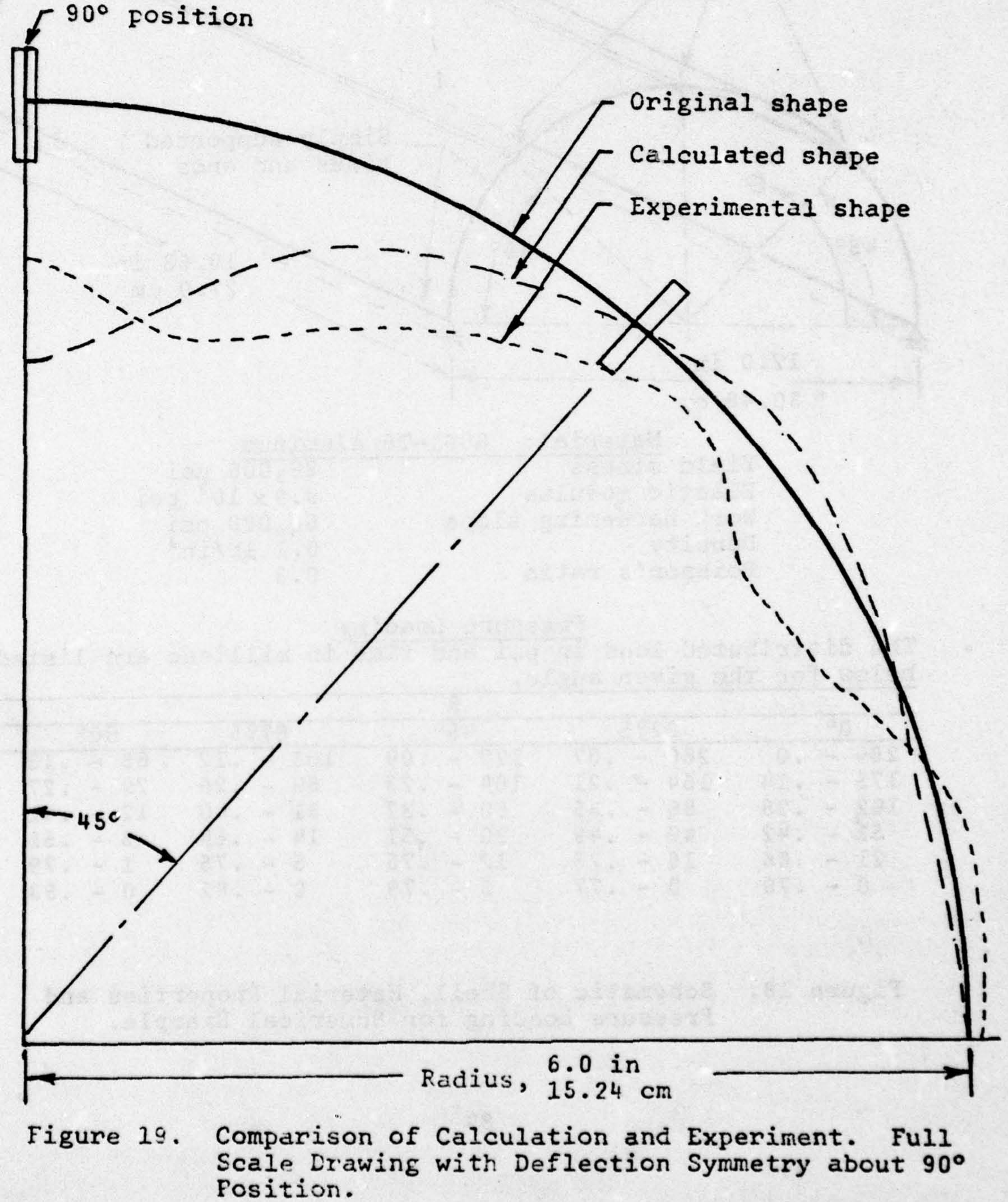


Figure 19. Comparison of Calculation and Experiment. Full Scale Drawing with Deflection Symmetry about 90° Position.

SECTION IV

CONCLUDING REMARKS

The emphasis of this study was specifically directed toward investigating the large plastic deformations of stiffened cylindrical shells subjected to blast loadings, that is, as associated with vulnerability studies. Many of the previous analyses and studies have not been considered in this report for reasons stated in previous sections. However, Jones (26) has recently completed a literature review of the dynamic plastic response of structures with many studies referenced in his review. The references contained in this study and those of Reference (26) represent a rather complete bibliography of both analytical and experimental plastic response of cylindrical shells.

The primary results of this study indicate that the effect of axially stiffening a cylindrical shell using stiffeners typical of those in aerospace applications is very small. This conclusion is based upon an analytical approach which incorporates the additional stiffness of the stiffeners into the energy equations directly by simply adding the reinforcing element to the potential and kinetic energy terms of the basic shell equation. This type of analysis thus eliminates bending-membrane coupling which would exist if anisotropic constitutive equations were introduced.

This conclusion has been verified by using two different methods for studying responses of the blast loaded shells and agrees with experimental tests conducted by the USAF Armament Lab, Eglin AFB, Florida. Both of the methods used have been incorporated into computer algorithms which allow an investigator to determine failure modes of blast loaded shells by either an engineering approach or a more sophisticated mathematical approach.

These data can then be used as first order approximations to examining failure regions at critical shell sections and attachment points.

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APPENDIX A

PROGRAM FOR GREENSPON SHELL THEORY WITH STIFFENERS

A-1 Introduction

The purpose of this program is to evaluate the total potential energy of shell configurations with/without stiffeners (stringers). The potential energy of the stiffened shell is divided into four parts, there being $\bar{V}_{1sh}$ and $\bar{I}_{1sh}$ for the shell and $\bar{V}_{1st}$ and $\bar{I}_{1st}$ for the stringers. These are given by the following equations:

$$\bar{V}_{1sh} = 4\int_0^{0.5}\int_0^{\pi} \Delta(x',\theta)\, d\theta\, dx' , \qquad [71]$$

$$\bar{I}_{1sh} = 4\int_0^{0.5}\int_0^{\pi} \left[\bar{\alpha}(x',\theta) + \frac{1}{3}\bar{\beta}(x',\theta)\right] d\theta\, dx' , \qquad [72]$$

$$\bar{V}_{1st} = \sum_{i=1}^{N} \Big[\frac{\sqrt{3}}{2}\left(\frac{w_o}{a}\right)^2\left(\frac{a}{L}\right)^2\left(\frac{\pi^2\Phi_i^2}{2}\right)\left(\frac{A_s}{at}\right) - \left(\frac{w_o}{a}\right)\left(\frac{a}{L}\right)\left(-2\pi\Phi_i\right)\left(\frac{\bar{z}}{L}\right)\left(\frac{A_s}{at}\right) \Big] , \qquad [73]$$

$$\bar{I}_{1st} = \sum_{i=1}^{N}\Big\{(1-\nu^2)\Big[\frac{1}{4}\left(\frac{w_o}{a}\right)^4\left(\frac{a}{L}\right)^2\left(\frac{3}{8}\pi^4\Phi_i^4\right)\frac{A_s}{at} - \left(\frac{w_o}{a}\right)^3\left(\frac{a}{L}\right)^3\left(-\frac{2}{3}\pi^3\Phi_i^3\right)\left(\frac{\bar{z}}{L}\right)\left(\frac{A_s}{at}\right) + \left(\frac{w_o}{a}\right)^2\left(\frac{a}{L}\right)\left(\frac{1}{2}\pi^4\Phi_i^2\right)\left(\frac{I_s}{atL^2}\right)\Big]\Big\} , \qquad [74]$$

$$\Phi_i = e^{-\frac{\theta_i}{4}} \cos(n\theta_i) \sin(\pi x') \ , \quad \theta_i = \begin{cases} \frac{2\pi i}{N} \ , & \frac{2\pi i}{N} \le \pi \\ 2\pi\left(1-\frac{i}{N}\right) \ , & \frac{2\pi i}{N} > \pi \end{cases} \qquad [75]$$

in which $\frac{w_0}{a}$ is the independent variable.

The procedure for evaluating the above energy terms is included in the user's manual, Section A.2.1, with a listing of the program variables used in Section A.2.3.

A.2 User's Manual

A.2.1 The formal procedure used to evaluate the two double integral types defined by $\bar{V}_{1sh}$ and $\bar{I}_{1sh}$ in equations [71] and [72] is given by the following steps:

(a) First evaluate the inner integrals keeping x' constant, that is,

$$\int_0^{\pi} \Delta(x';\theta) = \sum_{j=1}^{n_\theta} H_j \, \Delta(x';\theta_j) = F_1(x'), \qquad [76]$$

$$\int_0^{\pi} \left[\bar{\alpha}(x',\theta) + \frac{1}{3}\bar{\beta}(x',\theta)\right] d\theta \, dx'$$

$$= \sum_{j=1}^{n_\theta} H_j \left[\bar{\alpha}(x',\theta_j) + \frac{1}{3}\beta(x',\theta_j)\right] = F_2(x') \ . \qquad [77]$$

(b) Next, evaluate the outer integrals in a similar manner. We thus have

$$V_{1sh} = 4\int_0^{0.5} F_1(x')\,dx = 4\sum_{i=1}^{n_{x'}} H_i \, F_1(x_i'), \qquad [78]$$

$$I_{1pl} = 4\int_0^{0.5} F_2(x')\,dx = 4\sum_{i=1}^{n_{x'}} H_i F_2(x_i'), \qquad [79]$$

where n_θ and $n_{x'}$ are the number of steps choosen in θ and x' coordinates respectively. Hi and Hj are given by the combination of Simpson's rule and Newton's 3/8 rule, as contained in IBM System 1360 Scientific Subroutine Package (360 A-CM-03X) Version II (H20-0205-2), page 88.

A.2.2 Program Description

A.2.2.1 Usage

The program consists of a main program and three subroutines. In main program, two major steps are necessary: (1) to evaluate $\overline{V}_{1sh}$ and $\overline{I}_{1sh}$ by using the numerical integration scheme previously described; (2) to evaluate $\overline{V}_{1st}$ and $\overline{I}_{1st}$. If the input number of stringers is zero, then the second step is eliminated (see, for example the flow chart description of Figure 20). All input and output is included in the main program and all subroutines are also called from the main program.

A.2.2.2 Subroutine Required

DEL(DELTA,ALBT) evaluates the integrals given by equations [71] and [72] at the nodal points.

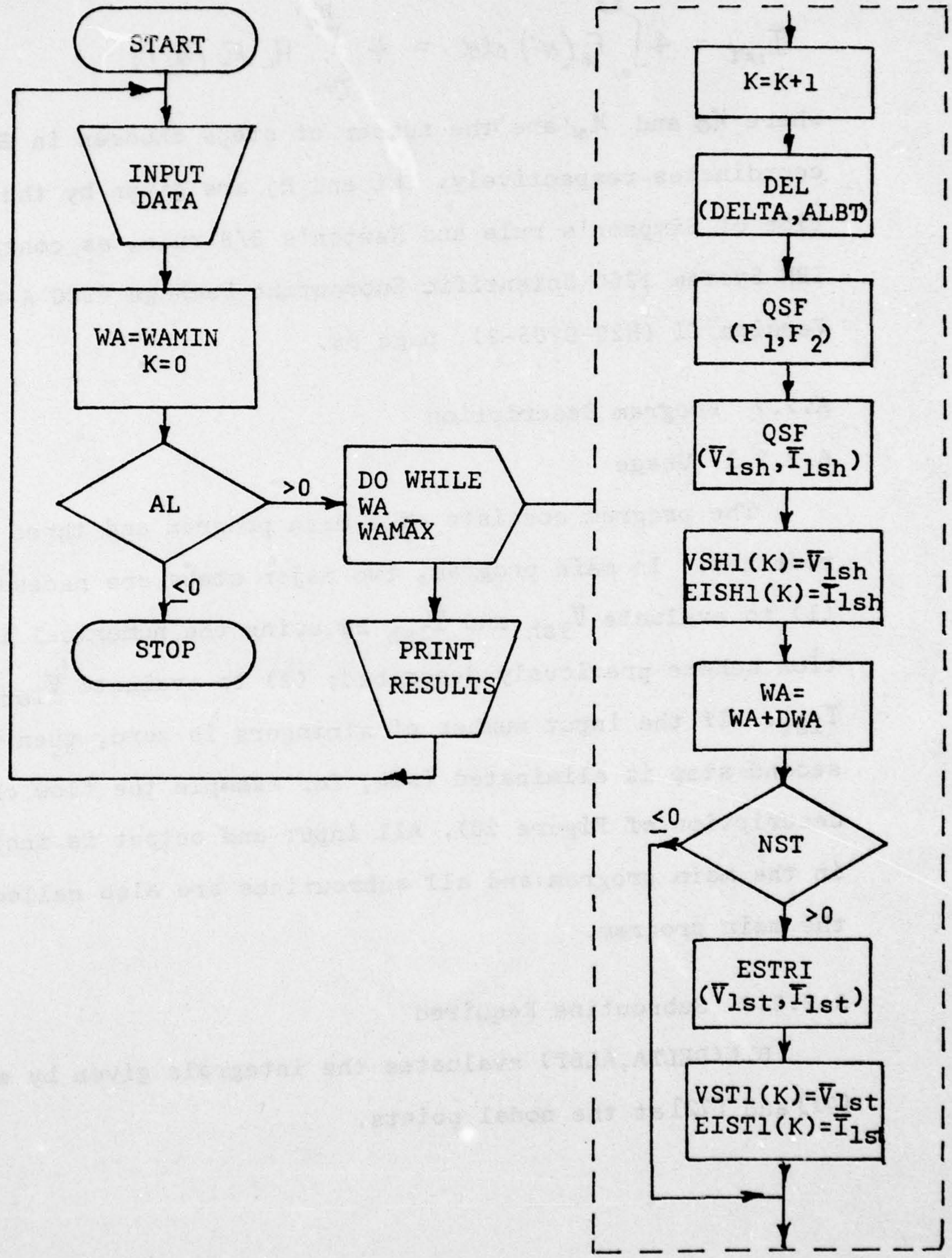

Figure 20. Flow Diagram for Greenspon Theory with Stiffeners.

QSF(DX,FY,FZ,NX) evaluates the integrals using a single integration. This subroutine is modified from the IBM supplied scientific subroutine QSF which has been referred to previously.

ESTRI(VST,EIST,NST,ARAT,ZAL) computes equations [73] and [74].

A.2.2.3 Program Variables

A	D/2
AK	K Out of roundness parameter, Equation 26
ALBT	Matrix of $\bar{\alpha}(X_i, Y_j) + \frac{1}{3}\bar{\beta}(X_i, Y_j)$ in equation [70] where i = 1, ..., NX and j = 1, ..., NY
AN	N
AREA	Area of stringer
D	Diameter of Shell
DELTA	Matrix of $\Delta(X_i, Y_j)$ in equation [71] where i = 1, ..., NX and j = 1, ..., NY
DT	D/T
DWA	Step size of WA
DX	Step size of X
DY	Step size of Y
EISH1	Vector of $\bar{I}_{1sh}$
EIST1	Vector of $\bar{I}_{1st}$
FY	Input vector of QSF

FZ	Output value of QSF
L	Length of shell
NP	Integer defined by (WMAX-WMIN)/DWA + 1
NST	Number of stringers
NX	Number of increments of X
NY	Number of increments of Y
SLD	L/D
T	Thickness of shell
U	Poisson's ratio
VSH1	Vector of $\overline{V}_{1sh}$
VST1	Vector of $\overline{V}_{1st}$
WA	WO/A
WA1	Vector of WA
WMAX	Upper bound of WA
WMIN	Lower bound of WA
WO	Radial displacement of Shell
X	X'
Y	Radial displacement of shell
ZBAR	Centroid of area

A.2.2.4 Dimension Requirements

The required dimension of the variables in the main program are, DELTA(NX,NY), ALBT(NX,NY), FY(NX), WA1(NP), VST1(NP), EISH1(NP) and EIST1(NP) where the parameters NX, NY and NP are defined in the description of variables used.

A.2.2.5 Input Formats

CARD TYPE	FORMAT	CONTENTS
1	3I5	NX, NY, NST
2	8F10.5	WAMIN, WAMAX, DWA, U, AK, T, AREA, ZBAR
3	2F10.5	SLD, DT
⋮		(CARD TYPE 3 may be repeated as may be necessary)
Final card	Blank	

A.2.2.6 Output

(1) If NST ≠ 0, the vectors WA1(K), VSH1(K), VST1(K), EISH1(K) and EIST1(K) are printed in columns.

(2) If NST = 0, the vectors WA1(K), VSH1(K), EISH1(K) are printed.

A.2.2.7 Summary of Users Requirements

(1) Determine values for NX, NY and NST. If NST = 0, then the values of T, AREA and ZBAR are neglected.

(2) Adjust the DIMENSION statements in main program and subroutines.

A.2.3 Test Problem

The following parameters were used to test the program:

NX = 26, NY = 26, NST = 8, WAMIN = .0125, WAMAX = .8, DWA = .05, U = .5, AK = .25, T = .0945, AREA = .063 and ZBAR = .2. The listing and output for this problem are contained in the following section.

A.3 Program Listing and Example Output

```
C                                                                    C
C     L      - LENGTH OF SHELL                                       C
C     D      - DIAMETER OF SHELL                                     C
C     A      - D/2                                                   C
C     T      - THICKNESS OF SHELL                                    C
C     DT     - D/T                                                   C
C     SLD    - L/D                                                   C
C     X      - X'                                                    C
C     Y      - RADIAL DISPLACEMENT OF SHELL                          C
C     WO     - RADIAL DISPLACEMENT OF SHELL                          C
C     WA     - WO/A                                                  C
C     WMAX   - UPPER BOUND OF WA                                     C
C     WMIN   - LOWER BOUND OF WA                                     C
C     DWA    - STEP SIZE OF WA                                       C
C     AREA   - AREA OF STRINGER                                      C
C     ZBAR   - CENTROID OF AREA                                      C
C     U      - PCISSON'S RATIO                                       C
C     AK     - K                                                     C
C     AN     - N                                                     C
C     NST    - NUMBER CF STRINGERS                                   C
C     NX,NY- NUMBER OF INCREMENTS OF X AND Y                         C
C
C
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSICN DELTA(26,26),FY(26),WA1(50),VSH1(50),VST1(50)
      DIMENSICN ALBT(26,26),EIST1(50),EISH1(50)
      COMMON U,PI,AK,AN,AL,TA,WA,DX,DY,NX,NY
      COMMON WA2,WA3,WA4,AL2,AL3,AL4,TA2,T
      READ 1,NX,NY,NST
    1 FORMAT(3I5)
      READ 3,WAMIN,WAMAX,DWA,U,AK,AREA,T,ZBAR
    3 FORMAT(8F10.5)
      PI=3.141593
C
C     INPUT SLD,DT
C
  140 READ 5,SLD,DT
    5 FORMAT(3F10.5)
      IF(DT.LE.0) GO TO 150
      AL=1./SLD/2.
      AL2=AL*AL
      AL3=AL2*AL
      AL4=AL3*AL
      TA=1./DT
      TA2=TA*TA
      AN=1.57*2.*AL*DSQRT(1.15/2./AL/DSQRT(TA)-1.)
      N=AN
      IF(AN-N.GE..5)N=N+1
      AN=N
      WA=WAMIN
      DX=1./(NX-1)
      DY=2.*PI/(NY-1)
      DX=DX/2.
      DY=DY/2.
      K=0
  130 K=K+1
      WA1(K)=WA
      WA2=WA*WA
      WA3=WA2*WA
      WA4=WA3*WA
C
C     EVALUATE DELTA AND ALPHA+BETA/3 AT  NODAL POINTS AND STORE IN
C     DELTA(I,J) AND ALBT(I,J) RESPECTIVELY
C
      CALL DEL(DELTA,ALBT)
```

```
C
C     EVALUATE V1SH
C
      DO 100 I=1,NX
      DO 110 J=1,NY
  110 FY(J)=DELTA(I,J)
      CALL QSF(DY,FY,FZ,NY)
  100 DELTA(I,1)=FZ
      DO 120 I=1,NX
  120 FY(I)=DELTA(I,1)
      CALL QSF(DX,FY,FZ,NX)
      VSH1(K)=4.*FZ
C
C     EVALUATE I1SH
C
      DO 190 I=1,NX
      DO 200 J=1,NY
  200 FY(J)=ALBT(I,J)
      CALL QSF(DY,FY,FZ,NY)
  190 ALBT(I,1)=FZ
      DO 210 I=1,NX
  210 FY(I)=ALBT(I,1)
      CALL QSF(DX,FY,FZ,NX)
      EISH1(K)=4.*FZ
      IF(NST.LE.0) GO TO 170
C
C     EVALUATE V1ST AND I1ST
C
      ARAT=AREA/(T*T*DT/2.)
      ZAL=ZBAR/(SLD*DT*T)
      CALL ESTRI(VST,EIST,NST,ARAT,ZAL)
      VST1(K)=VST
      EIST1(K)=EIST
  170 WA=WA+DWA
      IF(WA.LE.WAMAX) GO TO 130
      NP=K
      PRINT 30
   30 FORMAT(1H1)
      PRINT 10,SLD,DT,AK,AN,U
   10 FORMAT(////,17X,'L/D=',E15.5,/,17X,'D/T=',E15.5,/,17X,'K=',E15.5
     C     ,/,17X,'N=',E15.5,/,17X,'NU=',E15.5)
      IF(NST.LE.0) GO TO 180
      PRINT 12,ARAT,ZAL,NST
   12 FORMAT(17X,'AREA/A/T=',E15.5,/,17X,'ZBAR/A/T=',E15.5,/,
     C     17X,'NUMBER OF STRINGERS=',I5)
      PRINT 25
   25 FORMAT(/,28X,'WO/A',13X,'VSH1',13X,'VST1',13X,
     C     'ISH1',13X,'IST1',/)
      DO 160 I=1,NP
  160 PRINT 15,WA1(I),VSH1(I),VST1(I),EISH1(I),EIST1(I)
   15 FORMAT(15X,5(2X,E15.5))
      GO TO 140
  180 PRINT 40
   40 FORMAT(/,28X,'WO/A',13X,'VSH1',13X,'ISH1',/)
      DO 220 I=1,NP
  220 PRINT 35,WA1(I),VSH1(I),EISH1(I)
   35 FORMAT(15X,3(2X,E15.5))
      GO TO 140
  150 PRINT 30
      STOP
      END
```

```
      SUBROUTINE DEL(DELTA,ALBT)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSICN DELTA(26,26),ALBT(26,26)
      COMMON U,PI,AK,AN,AL,TA,WA,DX,DY,NX,NY
      COMMON WA2,WA3,WA4,AL2,AL3,AL4,TA2,T
      ASINH(X)=DLOG(X+DSQRT(1.+X*X))
      XX=-DX
      DO 100 I=1,NX
      XX=XX+DX
      YY=-DY
      DO 100 J=1,NY
      YY=YY+DY
      Y=YY
      X=XX
      IF(YY.GT.PI)Y=2.*PI-YY
      SPX=DSIN(PI*X)
      CPX=DCOS(PI*X)
      EKY=DEXP(-AK*Y)
      SNY=DSIN(AN*Y)
      CNY=DCOS(AN*Y)
      F=SPX*EKY*CNY
      FX=PI*CPX*EKY*CNY
      FY=-AN*SPX*EKY*SNY-AK*SPX*EKY*CNY
      FXX=-PI*PI*SPX*EKY*CNY
      FYY=2.*AN*AK*SPX*EKY*SNY+(AK*AK-AN*AN)*SPX*EKY*CNY
      FXY=-AN*PI*CPX*EKY*SNY-AK*PI*CPX*EKY*CNY
      IF(YY.LE.PI)GO TO 110
      FY=-FY
      FXY=-FXY
110   F2=F*F
      FX2=FX*FX
      FY2=FY*FY
      FX4=FX2*FX2
      FY4=FY2*FY2
      ALPHA=WA4*AL4*FX4/4.+WA4*AL2*FX2*FY2/2.-U*WA3*AL2*F*FX2
     C+WA4*FY4/4.-WA3*F*FY2+WA2*F2
      GAMMA=-WA3*AL4*TA*FX2*FXX-WA3*TA*FYY*FY2+2.*WA2*TA*FYY*F
     C-U*WA3*AL2*TA*FX2*FYY-U*WA3*AL2*TA*FXX*FY2+2.*U*WA2*AL2*TA
     C*F*FXX-4.*(1.-U)/2.*WA3*AL2*TA*FXY*FX*FY
      BETA=WA2*AL4*TA2*FXX*FXX+2.*U*WA2*TA2*AL2*FXX*FYY+WA2*
     CTA2*FYY*FYY+2.*(1.-U)*WA2*AL2*TA2*FXY*FXY
      DEL1=(2.*BETA+GAMMA)*DSQRT(ALPHA+GAMMA+BETA)/4./BETA
      DEL3=(-2.*BETA+GAMMA)*DSQRT(ALPHA-GAMMA+BETA)/4./BETA
      ABG=4.*ALPHA*BETA-GAMMA*GAMMA
      ABGLM=.1E-12
      IF(ABG.GT.-ABGLM.AND.ABG.LT.ABGLM) GO TO 120
      DEL2=(4.*ALPHA*BETA-GAMMA**2)/8./BETA/DSQRT(BETA)*ASINH
     C((2.*BETA+GAMMA)/DSQRT(4.*ALPHA*BETA-GAMMA**2))
      DEL4=(4.*ALPHA*BETA-GAMMA**2)/8./BETA/DSQRT(BETA)*ASINH
     C(( 2.*BETA+GAMMA)/DSQRT(4.*ALPHA*BETA-GAMMA**2))
      GO TO 130
120   DEL2=0
      DEL4=0.
130   DELTA(I,J)=DEL1+DEL2-DEL3-DEL4
      ALBT(I,J)=ALPHA+BETA/3.
100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE QSF(H,Y,Z,NDIM)
      IMPLICIT REAL*8 (A-H,O-Z)
C
C
      DIMENSION Y(26)
      COMMON U,PI,AK,AN,AL,TA,WA,DX,DY,NX,NY
      COMMON WA2,WA3,WA4,AL2,AL3,AL4,TA2,T
C
      HT=.3333333*H
      IF(NDIM-5)7,7,1
C
C     NDIM IS GREATER THAN 5. PREPARATIONS OF INTEGRATION LOOP
    1 SUM1=Y(2)+Y(2)
      SUM1=SUM1+SUM1
      SUM1=HT*(Y(1)+SUM1+Y(3))
      AUX1=Y(4)+Y(4)
      AUX1=AUX1+AUX1
      AUX1=SUM1+HT*(Y(3)+AUX1+Y(5))
      AUX2=HT*(Y(1)+3.875*(Y(2)+Y(5))+2.625*(Y(3)+Y(4))+Y(6))
      SUM2=Y(5)+Y(5)
      SUM2=SUM2+SUM2
      SUM2=AUX2-HT*(Y(4)+SUM2+Y(6))
      AUX=Y(3)+Y(3)
      AUX=AUX+AUX
      IF(NDIM-6)5,5,2
C
C     INTEGRATION LOOP
    2 DO 4 I=7,NDIM,2
      SUM1=AUX1
      SUM2=AUX2
      AUX1=Y(I-1)+Y(I-1)
      AUX1=AUX1+AUX1
      AUX1=SUM1+HT*(Y(I-2)+AUX1+Y(I))
      IF(I-NDIM)3,6,6
    3 AUX2=Y(I)+Y(I)
      AUX2=AUX2+AUX2
      AUX2=SUM2+HT*(Y(I-1)+AUX2+Y(I+1))
    4 CONTINUE
    5 Z=AUX2
      RETURN
    6 Z=AUX1
    7 RETURN
      END
```

```
      SUBROUTINE ESTRI(VST,EIST,NST,ARA,ZL)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON U,PI,AK,AN,AL,TA,WA,DX,DY,NX,NY
      COMMON WA2,WA3,WA4,AL2,AL3,AL4,TA2,T
      VST=0
      EIST=0.
      N1=NST
      DO 10 I=1,N1
      J=I-1
      Y=2.*PI*J/N1
      IF(Y.GT.PI) Y=2.*PI-Y
      PHI=DEXP(-AK*Y)*DCOS(AN*Y)
      PHI2=PHI*PHI
      PHI3=PHI*PHI2
      PHI4=PHI2*PHI2
      PI2=PI*PI
      PI3=PI*PI2
      PI4=PI2*PI2
      VST1=1.7320508*WA2/2.*AL2*PI2*PHI2/2.*ARA
      VST2=1.7320508*WA*AL*2.*PI*PHI*ZL*ARA
      VST=VST+VST1+VST2
      UU1=1.-U*U
      EIST1=UU1*.25*WA4*AL2*3./8.*PI4*PHI4*ARA
      EIST2=UU1*WA3*AL3*2./3.*PI3*PHI3*ZL*ARA
      EIST3=UU1*WA2*AL2*.5*PI4*PHI2*(ZL+TA*AL)**2*ARA
      EIST=EIST+EIST1+EIST2+EIST3
   10 CONTINUE
      RETURN
      END
```

Example Output

```
L/D=      0.10000D 01
D/T=      0.20000D 03
K=     0.25000D 00
N=     0.60000D 01
NU=      0.50000D 00
AREA/A/T=      0.23810D 00
ZBAR/A/T=      0.15873D-01
NUMBER OF STRINGERS=     8
```

WO/A	VSH1	VST1	ISH1	IST1
0.12500D-01	0.44880D-01	0.11137D-03	0.12696D-03	0.26448D-06
0.62500D-01	0.26035D 00	0.22419D-02	0.43567D-02	0.16010D-04
0.11250D 00	0.58740D 00	0.70687D-02	0.23622D-01	0.11996D-03
0.16250D 00	0.10546D 01	0.14592D-01	0.80957D-01	0.47089D-03
0.21250D 00	0.16596D 01	0.24811D-01	0.21285D 00	0.13168D-02
0.26250D 00	0.24101D 01	0.37726D-01	0.46922D 00	0.29948D-02
0.31250D 00	0.33091D 01	0.53337D-01	0.91347D 00	0.59315D-02
0.36250D 00	0.43562D 01	0.71645D-01	0.16224D 01	0.10642D-01
0.41250D 00	0.55531D 01	0.92649D-01	0.26864D 01	0.17732D-01
0.46250D 00	0.69011D 01	0.11635D 00	0.42090D 01	0.27895D-01
0.51250D 00	0.84009D 01	0.14274D 00	0.63076D 01	0.41915D-01
0.56250D 00	0.10052D 02	0.17184D 00	0.91126D 01	0.60664D-01
0.61250D 00	0.11853D 02	0.20363D 00	0.12768D 02	0.85103D-01
0.66250D 00	0.13804D 02	0.23811D 00	0.17432D 02	0.11628D 00
0.71250D 00	0.15906D 02	0.27529D 00	0.23275D 02	0.15535D 00
0.76250D 00	0.18159D 02	0.31517D 00	0.30481D 02	0.20352D 00

APPENDIX B

PROGRAM FOR MENTE DEPROP CODE WITH STIFFENERS (DEPROSP)

B.1 Introduction

The modified DEPROP code will be called DEPROSP, acronym for Dynamic Elastic Plastic Response of Stiffened Panels. The DEPROSP program has all the capabilities of DEPROP plus the capability of handling axially stiffened flat and cylindrical panels for a single layer of isotropic material. The stiffeners (stringers) must be of the same material as the shell and have the same boundary conditions. All the provisions of the DEPROP program as pertaining to either static or dynamic loadings remains the same. The words stiffener and stringer as used interchangably here and in the text have the same meaning, i.e., the axial stiffening element added to panel.

In Section B.2 the subroutines are listed and described, flow diagrams are shown, and the major program variables are listed. Program input data is given in Section B.3 and program output and error messages are described in Section B.4. A complete program listing is given in Section B.5.

B.2 Description of Subroutines, Flow Diagrams, and Program Variables

B.2.1 Subroutines and Flow Diagrams

Table IX lists the 19 routines and all common blocks which make up DEPROSP. The decimal length of each common is also indicated.

TABLE IX. DEPROSP ROUTINES AND COMMON BLOCKS

COMMON	FIRST	CNOVA	CLOAD	CBLK1	CBLK2	CBLK3	CBLK4	CBLK5	CBLK6	CBLK7	CBLK8	CBLK9	CBLK10	CBLK11	CBLK12	CBLK13	CBLK14	CHIM	BLANK
Length of Common	1	142	1072	228	4409	40	5440	1197	33550	30	891	162	5415	14	22638	9	988	148	20174
Routine DEPROSP	X	X	X																
BOLT				X	X														
DERV2		X		X	X	X	X				X		X	X			X		X
DSET1		X		X	X	X	X	X		X	X	X	X	X		X	X		X
DSET2		X		X	X	X	X	X		X	X	X	X	X		X			X
DSET3		X		X	X	X	X	X		X	X	X	X	X		X	X		X
DTSTEP		X		X	X											X			
HIM																		X	
LEGEND				X		X													
LIST1		X		X							X	X	X				X		X
LIST2		X		X						X	X	X	X				X		X
PINIT		X	X	X							X								X
PRESS		X	X	X							X								X
PROP	X	X		X	X	X	X	X		X	X	X	X	X		X	X		X
REIT				X		X				X			X	X			X		X
RELAXP															X				
SEC																			
SIGMA		X		X		X	X		X	X									X
SOLVE																			

Flow diagrams of the major routines are presented in Figures 21 to 26, while brief descriptions of the purpose of all the routines are given below. Also included are lists of the routines which are referenced by other routines and vice-versa.

DEPROSP

Main program. Reads preliminary input data and controls program flow. Calls PINIT, PROP.

BOLT

Sets up W mode shapes for boundary conditions selected.
Called by DSET3.

DERV2

Computes strains, displacements, and accelerations in the main integration loop.
Calls LIST1, LIST2, PRESS, REIT, SIGMA, SOLVE.
Called by PROP.

DSET1

Reads DEPROSP input data and calculates constants.
Called by PROP.

DSET2

Calculates constants used in DEPROSP.
Calls LEGEND, DTSTEP.
Called by PROP.

DSET3

Calculates additional constants and writes out a description of input data.
Calls BOLT.
Called by PROP.

DTSTEP

Computes an integration time step small enough to avoid numerical instabilities.
Called by DSET2.

HIM

Numerical timewise integration routine.
Called by PROP.

LEGEND

Sets up constants for Gaussian integration through the thickness for an elastic-plastic solution.
Called by DSET2.

LIST1

Output routine for the elastic-only option.
Called by PROP, DERV2.

LIST2

Output routine for the elastic-plastic option.
Called by PROP, DERV2.

PINIT

Reads in pressure loading time history. Sets up loading functions.
Called by PROP.

PRESS

Calculates pressure loading at a given time.
Called by DERV2.

PROP

Executes the static and dynamic panel solutions.
Calls DERV2, DSET1, DSET2, DSET3, HIM, LIST1, LIST2, RELAXP, SEC.
Called by DEPROSP.

REIT

Computes reaction forces at the boundaries and corners.
CALLED BY DERV2.

RELAXP

Solves simultaneous nonlinear equations representing preblast conditions using a relaxation procedure.
Calls SOLVE.
Called by PROP.

SEC

Finds elapsed CP time.
Calls system routine SECOND.
Called by PROP.

SIGMA

Computes stresses in the main integration loop for the elastic-plastic option. Is not needed for the elastic-only option.
Called by DERV2.

SOLVE

Solves a set of simultaneous linear algebraic equations.
Called by DERV2, RELAXP.

B.2.2 Major Program Variables

The major program variables are defined in this subsection. These variables are listed alphabetically with a brief description devoted to each one. An asterisk preceding a variable name indicates that the variable is input as run data. The dimension of a variable is given parenthetically after the variable name, where a numerical dimension indicates the fixed amount of storage required for the variable. There is no need to change the dimension of such a variable. However, other variables have variable dimensions. As an example, one of the first dimensioned variables listed is BETR(NBAR). The dimension is a variable, NBAR, which represents the number of spatial

integration points used in the beta-direction in the panel. This dimension must be the largest number of points the user intends to employ. In the DEPROSP program, this dimension is 23. If additional integration points are required, the dimension of NBAR must be increased, thus increasing the dimensions for all variables with the dimension, NBAR. The current dimensions provided for the variables in the DEPROSP routines are given in Table X.

Almost all of the variables which may require dimension changes as indicated above are contained in the COMMON blocks. There are a few exceptions and, in such cases, the subroutine in which the variable is dimensioned is indicated in the list of variables or in Table XI. If the dimensions are changed, certain additional changes in the program may be required. These changes are also indicated in Table XI.

Many of the variables found in the program result from their use in the larger NOVA-2 code (Reference 25). In most cases, these variables have little or no use in DEPROSP and are so indicated.

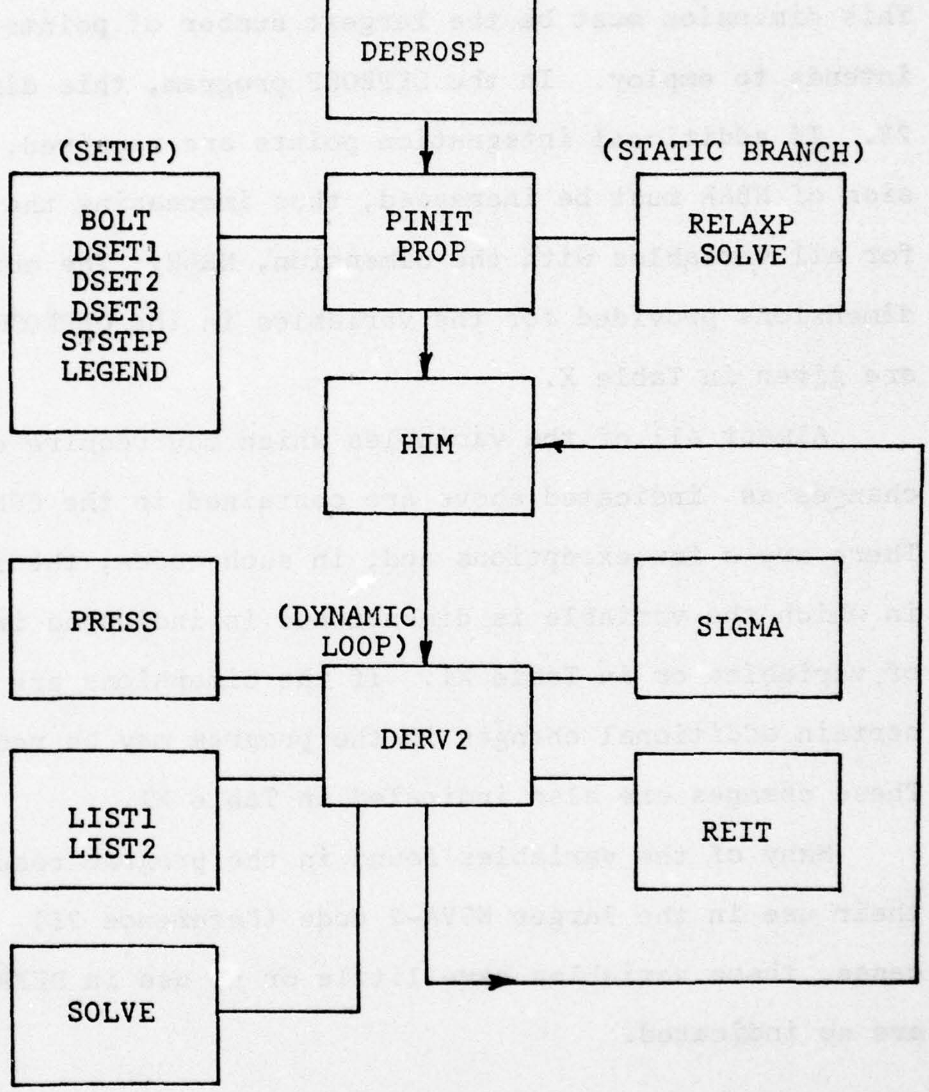

Figure 21. Major Program Flow (DEPROSP).

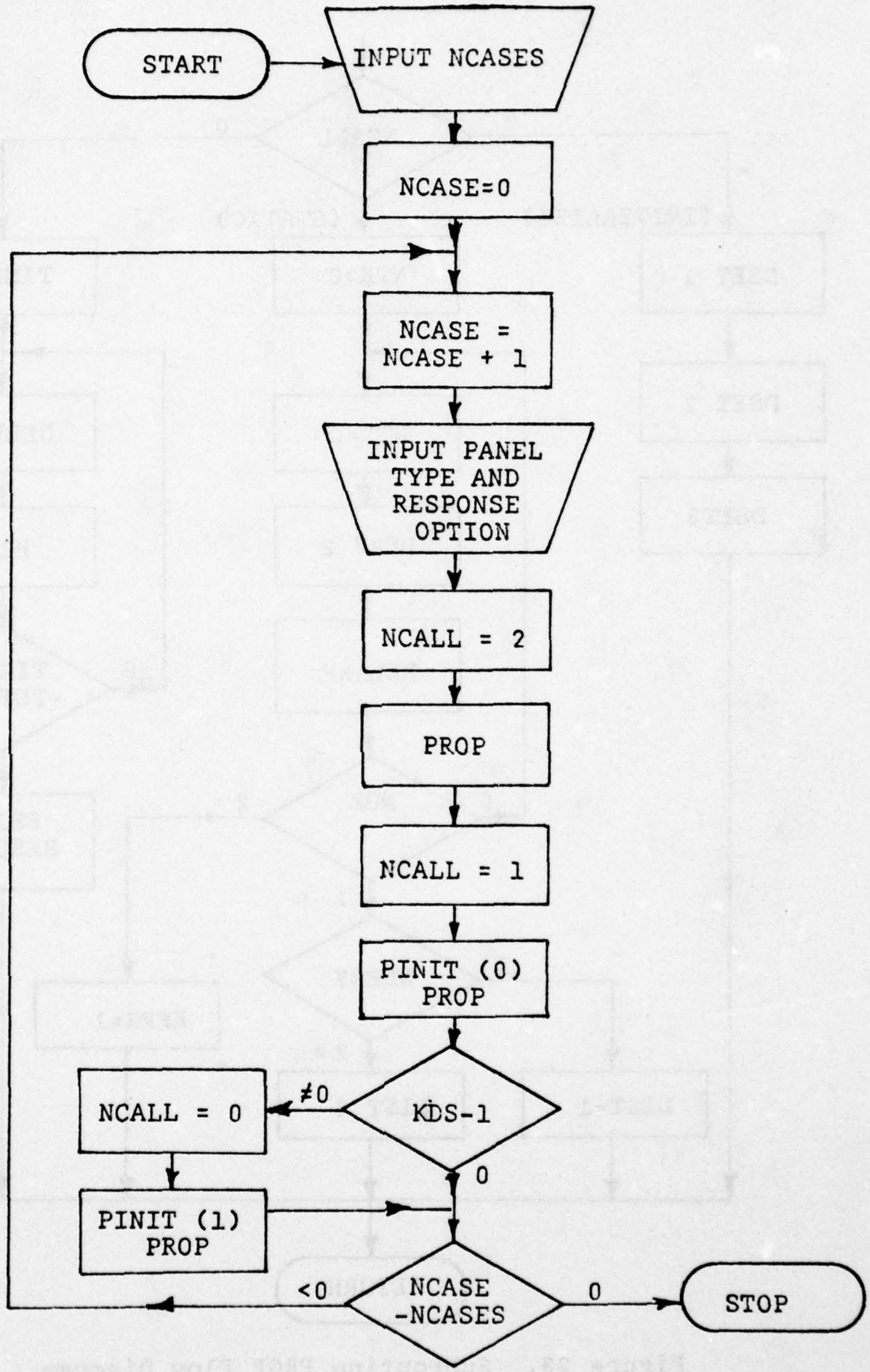

Figure 22. Program DEPROSP Flow Diagram.

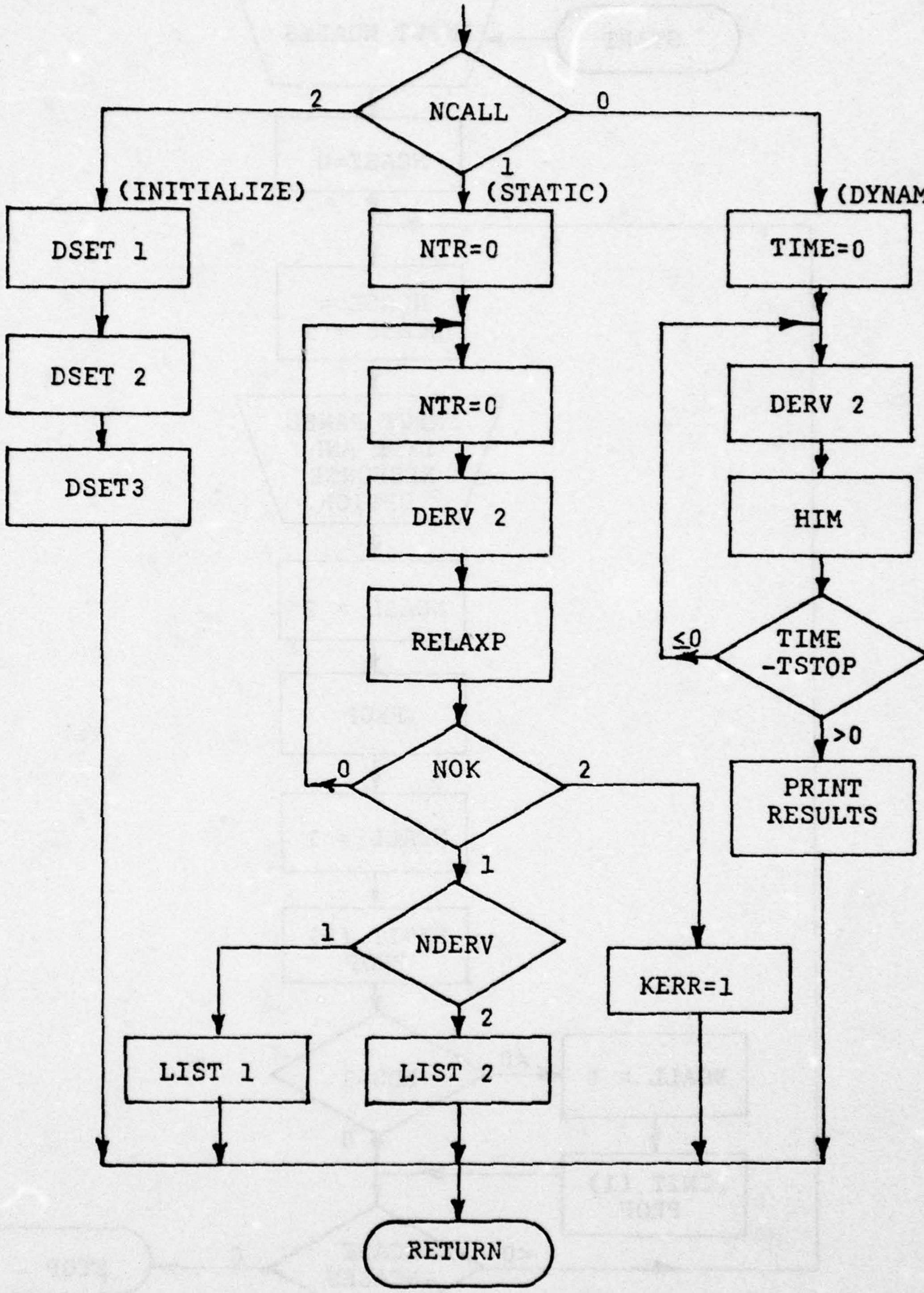

Figure 23. Subroutine PROP Flow Diagram.

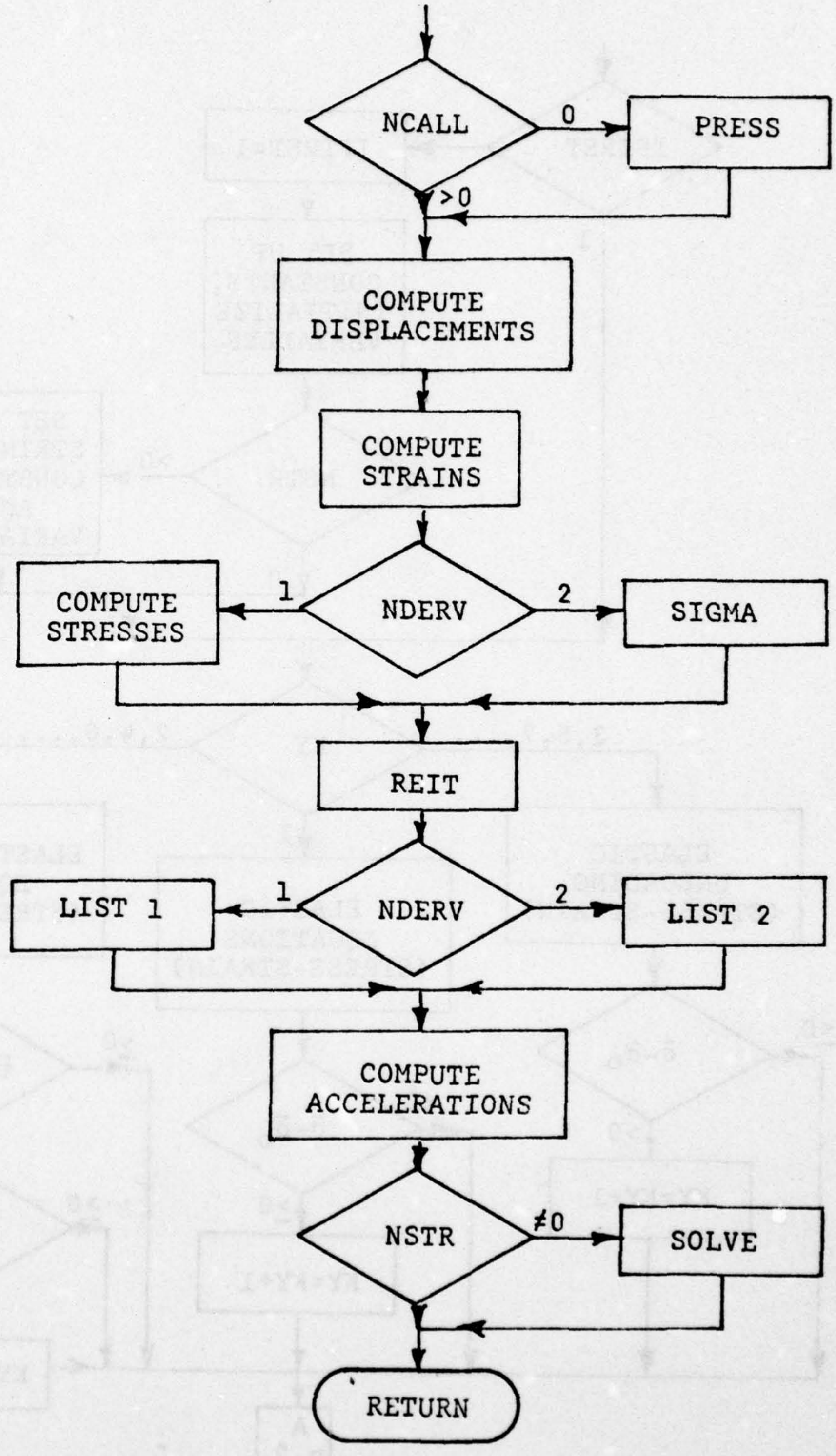

Figure 24. Subroutine DERV2 Flow Diagram.

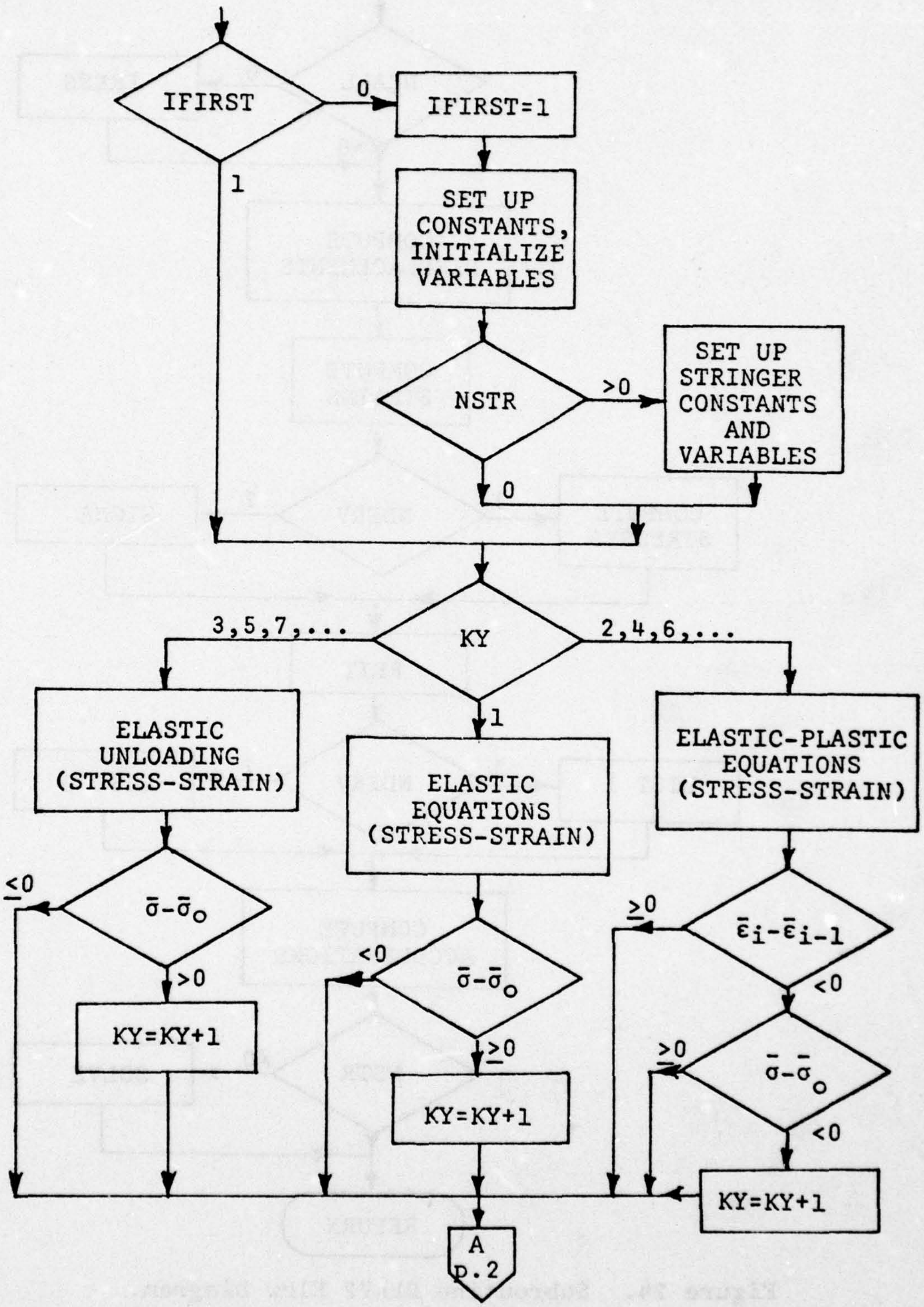

Figure 25. Subroutine SIGMA Flow Diagram, Part 1.

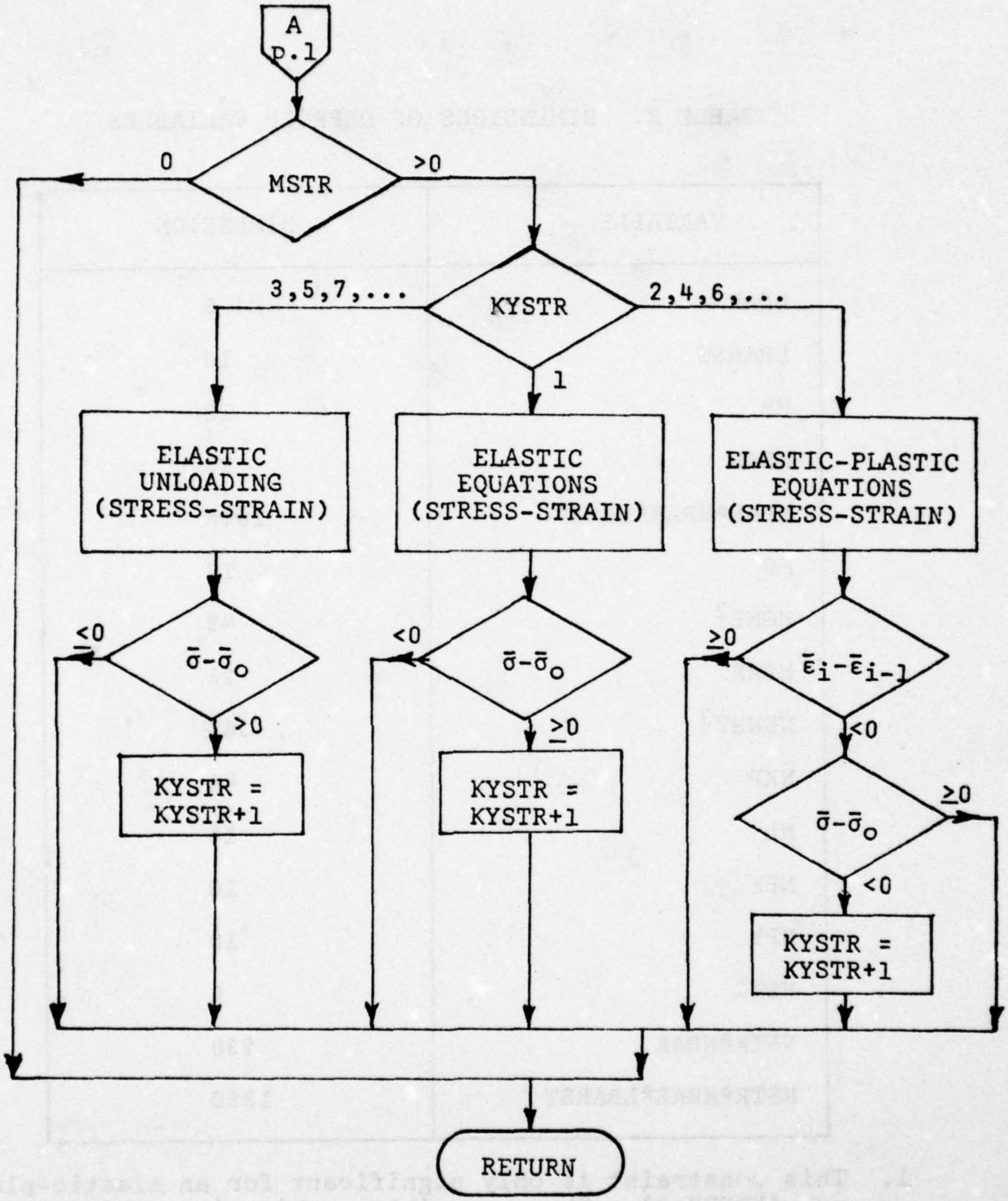

Figure 26. Subroutine SIGMA Flow Diagram, Part 2.

TABLE X. DIMENSIONS OF DEPROSP VARIABLES

VARIABLE	DIMENSION
LBAR	6
LBARST	10
MB	13
MBAR	23
MBAR*NBAR*LBAR[1]	1805
MG	13
MGMB[2]	49
NBAR	23
NBNBT[3]	361
NKP	46
NL	15
NPX	10
NPY	10
NSTR	6
NSTR*NBAR	230
NSTR*NBAR*LBARST	1380

1. This constraint is only significant for an elastic-plastic run (NDERV=2). Three possible combinations using maximum dimensions are: (17x17x6), (19x19x5), (21x21x4).
2. The total number of modes selected (MGMB) from the total possible (MB*MG) cannot exceed 49.
3. The total number of spatial integration points allowed (NGNBT) from the total possible (MBAR*NBAR) is 361.

TABLE XI. PROGRAM CHANGES REQUIRED BY DIMENSION CHANGES

When Changing the Dimensions Corresponding to:	Also Change the Fixed-Point Number in the Indicated Statement	
	Subroutine	Location[1]
MGMB*3	HIM	COMMON BLOCK
LBAR	LEGEND	300^{-11}
LBARST	LEGEND	350^{+3}
MGMB*3	RELAXP	20^{+1}

[1]The location code is read as follows: s^{+n} refers to the nth line sfter statement number s.

B.2.3 List of Program Variables

*A	Radius of the cylindrical panel, a, in. Is set equal to 1.0 for flat panel
*AA	Pressure loading parameter, a, dimensionless (Load Option 3)
ALTT(LMAX)	Change in stress component, $\tilde{\alpha}_{\theta\theta}$, psi
ALXT(LMAX)	Change in stress component, $\tilde{\alpha}_{x\theta}$, psi
ALXX(LMAX)	Change in stress component, $\tilde{\alpha}_{xx}$, psi
ALXXST(LMAXST)	Change in stringer stress component, $\tilde{\alpha}_{xx}$, psi
*ANN	Pressure loading parameter, n, dimensionless (Load Option 3)
AZ	Constant equal to a/t_o, 1/sec (Load Option 3)
AAU(MGMB,MGMB)	Matrix of $\ddot{U}_{mn}$ coefficients, making up part of the set of simultaneous linear algebraic equations used in stringer calculations, $1/sec^2$
AAW(MGMB,MGMB)	Matrix of $\ddot{W}_{mn}$ coefficients, making up part of the set of simultaneous linear algebraic equations used in stringer calculations, $1/sec^2$
BBU(MGMB)	Right hand side vector of computed constants making up part of the set of simultaneous linear algebraic equations for stringer calculation of U_{mn}, $1/sec^2$
BBW(MGMB)	Right hand side vector of computed constants making up part of the set of simultaneous linear algebraic equations for stringer calculation of W_{mn}, $1/sec^2$
BE1(LMAX)	Change in strain component, $\tilde{\beta}_{xx}$, in/in.
BE2(LMAX)	Change in strain component, $\tilde{\beta}_{\theta\theta}$, in/in.

BE3(LMAX)	Change in strain component, $\tilde{\beta}_{x\theta}$, in/in.
BE4(LMAXST)	Change in stringer strain component, $\tilde{\beta}_{xx}$, in/in.
BETR(NBAR)	Integration positions in the beta-direction, rad
BTL(NL)	Constants used in elastic option, $E^k_\theta/(1-\nu^k_x\nu^k_\theta)$, psi
*BSTR	Width of stringer, b_s, in.
BXL(NL)	Constants used in elastic option, $E^k_x/(1-\nu^k_x\nu^k_\theta)$, psi
BXLST(NL)	Constants used in elastic option for stringers, E^k_x, psi
CCRIT(NL)	Not used
CC1(MG)	Constant, m, dimensionless
CC2(MB)	Constant, n, dimensionless
CC5(MG)	Constant, m+1, dimensionless
CC6(MB)	Constant, n+1, dimensionless
CINST(3)	Not used
CK(6)	Constants, $1/k_\gamma$, $1/k_\beta$, for the equations of motion, dimensionless
CM11, CM12, CM22, CM33	Stiffness constants C_{ij} used in elastic, multi-layer integration through the thickness, lb/in.
CM11ST	Stiffness constant C_{11} used in elastic, single layer integration through the stringer thickness, lb/in.
CN10	Constant, $2L^2R$ for elastic option, $2L^2$ for elastic-plastic option, dimensionless

CN11	Constant, $2L^2R$ for elastic option, $L^2/6R^2$ for elastic-plastic option, dimensionless
CN6	Constant for elastic-plastic option, $E/(1-\nu^2)$, psi
CN7	Shear modulus for elastic-plastic option, $E/2(1+\nu)$, psi
CN8	Constant, L^2, dimensionless
CN9	Constant, $L^2/2R$, dimensionless
COSB(MB*NBAR)	Cosine functions of the beta angles, $\cos((n+1)\beta_j)$, dimensionless
COSG(MG*MBAR)	Cosine functions of the gamma angles, $\cos((m+1)\gamma_i)$, dimensionless
COS2B(MB*NBAR)	Cosine functions of the beta angles, $\cos(n\,\beta_j)$, dimensionless
COS2G(MG*MBAR)	Cosine functions of the gamma angles, $\cos(m\,\gamma_i)$, dimensionless
CRIT(3)	Not used
DC	Not used
DELT	Grid point spacing in β-direction, Δy, in., or $a\Delta\theta$, in-rad
*DELTIM	Integration time interval, sec
DELX	Grid point spacing in γ-direction, Δx, in.
DELX(3*MGMB)	Working array in RELAXP, dimensionless
*DET(NPY,NPY)	Delay time to when spatial point is first engulfed by pressure wave, sec (Load Option 2)
DM11, DM12, DM22, DM33	Stiffness constants D_{ij} used in elastic, multilayer integration through the thickness, lb/in.

DM11ST	Stiffness constant D_{11} used in elastic, single layer integration through the stringer thickness, lb/in.
DPRT	Running time, in multiples of DPRT1, used to flag next printout, sec
DPRT1	Time interval between printouts, sec
*DTIM	Time interval between specified pressure data, sec (Load Option 2)
DWB(NGNBT)	Values for imperfection-related partial derivative $\mathring{W}_{\beta}$, dimensionless
DWG(NGNBT)	Values for imperfection-related partial derivatives $\mathring{W}_{\gamma}$, dimensionless
DWO(NGNBT)	Values for imperfection-related displacement $\mathring{W}$, dimensionless
DX1(MBAR)	Fractional distance in γ-direction, locating grid point between two pressure-mesh points, dimensionless (Load Option 2)
DY1(NBAR)	Same as DX1, only in β-direction
EC	Not used
EL	Modulus of elasticity for elastic-plastic option, E, psi
*EM(NL)	Modulus of elasticity for each layer for elastic-plastic option, E^k, psi
ENX(2*NBAR-2)	Tangential reaction force per unit length along boundary, N_x, lb/in.
ENT(2*MBAR-2)	Tangential reaction force per unit length along boundary, N_{θ}, lb/in.
*EP	Strain hardening slope for elastic-plastic option, E_t, psi
EPB(LMAX)	Temporary storage used for either $\bar{\varepsilon}$ or $\bar{\sigma}$

EPBO(LMAX)	Equivalent stress, squared, when response is still elastic for the elastic-plastic option, $\bar{\sigma}^2$, lb^2/in^4.
EPBOST(LMAXST)	Equivalent stringer stress, squared, when response is still elastic for the elastic-plastic option, $\bar{\sigma}_s^2$, lb^2/in^4
EPBSTR(LMAXST)	Temporary storage used for stringer variables $\bar{\varepsilon}$ or $\bar{\sigma}$
EPO	Equivalent yield strain corresponding to SIGO for elastic-plastic option, $\bar{\varepsilon}_o$, in/in.
*EPSIF	Ultimate (fracture) strain for elastic-plastic option, ε_f, in/in; not used
ERR(3*MGMB)	Allowable error in displacement coefficients in the static solution
*ET(NL)	Modulus of elasticity in the theta-direction for elastic option, E_θ^k, psi
ETT	Temporary value of strain, $\varepsilon_{\theta\theta}^m$, in/in.
ETT1(LMAX)	Strain component at the time of last yielding, $\varepsilon_{\theta\theta}$, in/in.
*EX(NL)	Modulus of elasticity in x-direction for elastic option, E_x^k, psi
EXT	Temporary value of strain, $\varepsilon_{x\theta}^m$, in/in.
EXT1(LMAX)	Strain component at the time of last yielding, $\varepsilon_{x\theta}$, in/in.
EXX	Temporary value of strain, ε_{xx}^m, in/in.
EXXSTR	Temporary value of stringer strain, ε_{xx}^m, in/in.
EXXST1(LMAXST)	Stringer strain component at the time of last yielding, ε_{xx}, in/in.
EXX1(LMAX)	Strain component at the time of last yielding, ε_{xx}, in/in.

*FG(MB,MB)	Modal displacement coefficients for the initial imperfections, in.
FM11, FM12 FM22, FM33	Stiffness constants F_{ij} used in elastic, multilayer integration through the thickness, lb
FP1(G*MBAR)	Displacement function, $\phi_m^w(x)$, dimensionless
FP2(MG*MBAR)	$\frac{\partial}{\partial\gamma}\phi_m^w(x)$, dimensionless
FP3(MG*MBAR)	$\frac{\partial^2}{\partial\gamma^2}\phi_m^w(x)$, dimensionless
FP4(MG,2)	$\frac{\partial^3\phi_m^w}{\partial\gamma^3}$ at $\gamma = 0, \pi$, dimensionless
FP5(MB*NBAR)	Displacement function, $\phi_n^w(\theta)$, dimensionless
FP6(MB*NBAR)	$\frac{\partial\,\phi_n^w(\theta)}{\partial\beta}$, dimensionless
FP7(MB*NBAR)	$\frac{\partial^2\phi_n^w(\theta)}{\partial\beta^2}$, dimensionless
FP8(MB,2)	$\frac{\partial^3\phi_n^w(\theta)}{\partial\beta^3}$ at $= 0, \pi$, dimensionless
GAM(MBAR)	Integration positions in the γ-direction, rad
GAMMA(41)	Not used
GC	Not used
GX(LBAR)	Zeroes of the Legendre polynomial for the elastic-plastic Gaussian integration through the thickness, ξ_i, dimensionless
GXSTR(LBARST)	Zeroes of the Legendre polynomial for the elastic-plastic Gaussian integration through the stringer thickness, ξ_{si}, dimensionless

*GXT(NL)	Shear modulus, $G_{x\theta}$, psi
H	Thickness of cross section for elastic-plastic option, in.
HBAR	Distance from the inner panel surface to the coordinate surface, H, in.
HGO(LBAR)	Weighting factors for the elastic-plastic Gaussian integration through the thickness, H_i, dimensionless
HGOSTR(LBARST)	Weighting factors for the elastic-plastic Gaussian integration through the stringer thickness, H_{si}, dimensionless
*HM(NL)	Distance from the inner panel surface to the outer surface of layer, h, in.
*HSTR	Thickness of the stringer cross-section for the elastic-plastic option, in.
ICOMP	Not used
ICOUNT	Counter, initially set at 37777000000000000000B, and incremented for each integration step in program
IFIRST	Code designating first pass through subroutine SIGMA, dimensionless
IMASTR	Code which indicates if integration point currently under consideration has a stringer associated with it
INOUT	Not used
INZ(2)	Code designating the appropriate layer number corresponding to the two panel surfaces, dimensionless
INZSTR(2)	Code designating the appropriate layer number corresponding to the two stringer surfaces, dimensionless
IP(3*MGMB)	Working array in RELAXP, dimensionless

IXI(MBAR)	Integer locating grid points in γ-direction relative to pressure-mesh (Load Option 2)
JFIRST	Code which indicates if the panel has yielded for the elastic-plastic option
JL	Lower index on timewise interpolation table (Load Option 4)
JLT(NPY,NPX)	Lower index on timewise interpolation table (Load Option 2)
JSTRFT	Code which indicates if stringer has yielded for the elastic-plastic option
JYJ(NBAR)	Integer locating grid points in β-direction relative to pressure-mesh (Load Option 2)
KALT	Not used
KB	Not used
KC	Not used
KDAM	Not used
*KDS	Response option code
KERR	Dynamic response error code - 0, no error; 1, error
KOK	Not used
*KPG(NKP)	Mesh point number (γ), when paired with KPB, calling for printout
*KPB(NKP)	Mesh point number (β), when paired with KPG, calling for printout
KSUMA(NGNBT)	Number of z points which have not yielded at each spatial station; used only in elastic-plastic option
KSUMAS(NSTR*NBAR)	Number of stringer z points which have not yielded at each spatial station; used only in elastic-plastic option

*KTYPE	Code designating panel type 1, single-layer metal 2, honeycomb panel (3 layers) 5, multilayer panel (elastic response only)
KY(LMAX)	Code in elastic-plastic response, indicating number of times an integration point has yielded, unloaded, etc.
KYSTR(LMAXST)	Code in elastic-plastic response, indicating number of times a stringer integration point has yielded, unloaded, etc.
KZ	Code deciding whether the output routine should print
*LBAR	Number of integration points through the panel thickness; is assumed to be one for elastic option
*LBARST	Number of integration points through the stringer thickness; is assumed one for elastic option
LMAX	Maximum number of integration points being used; equal to MBAR*NBAR*LBAR
LMAXST	Maximum number of integration points involving stringers which are being used; equal to NSTR*LBARST*NBAR
*LOCSTR(NSTR)	Integration positions in beta direction matching stringer positions
*MB	Number of beta modes to be incorporated into the solution
*MBAR	Number of gamma integration points to be used; for a symmetric boundary condition, only approximate half as many points are required
*MBSTR	Number of stringers to be used; for a symmetric boundary condition in the beta direction, only approximate half as many are required

*MG	Number of gamma modes to be incorporated into the solution
*MGM(MG)	Gamma mode numbers
MGMB	Constant, equal to the total number of modal combinations used, MG*MB-NNOUT
MGMB2	Constant, 2*MGMB
*MOUT(MG*MB)	Gamma modes not to be included, in combination with the corresponding NOUT mode
MUSE(MB,MG)	Code designating which modal combinations are to be used
NB	Beta-point number corresponding to centerline of panel
*NBAR	Number of beta integration points to be used; for a symmetric boundary condition, only approximately half as many points are required as otherwise
*NBN(MB)	Beta mode numbers
*NBND	Boundary condition code
NBT	Total number of beta points monitored
NCALL	Code describing program phase: 0, find dynamic response 1, find static solution 2, read data, set up constants
NCASE	Case number currently being run
*NCASES	Number of cases to be run
NCHPT	Not used
*NDBUG	Output debugging control: 0, no debug output (normal option) 1, most debug output 2, all debug output

*NDERV	Response code: 1-elastic (multilayer, orthotropic), 2-elastic-plastic (single layer, isotropic)
NELP	Response code for the elastic-plastic option: 1-keep solution elastic, 2-allow solution to go elastic-plastic
NG	Gamma-point number corresponding to center line of panel
NGNB	The spatial integration point number corresponding to the center of the panel
NGNBT	Total number of spatial integration points used
NGT	Total number of gamma points monitored
*NKP	Number of spatial points for which printout of strains, stresses, reactive forces, displacements and pressure is required
*NL	Number of layers
*NLOAD	Pressure load option code: 1, nonuniform, functions 2, nonuniform, discrete 3, uniform, functions 4, uniform, discrete
NLZ(2*NL)	Layer number corresponding to each layer's upper and lower surfaces
NMASS	Not used
*NNOUT	Number of modal combinations (<MG*MB) to be eliminated from the solution
*NOUT(MG*MB)	Beta modes not to be included, in combination with the corresponding MOUT mode
*NPLT	Panel type code: 0-flat, 1-curved
*NPX	Number of mesh points in γ-directions for which pressure data is provided (Load Option 2)

*NPY	Number of mesh points in β-direction for which pressure data is provided (Load Option 2)
NREG	Not used
NSTR	Number of stringers actually needed in calculations; MBSTR or (MBSTR+1)/2, truncated
*NSYMB	Symmetry code in the beta-direction: 0-symmetric, 1-not symmetric
*NSYMG	Same as NSYMB, except in the gamma-direction
NTECO	Not used
*NTIME	Number of times for which pressure data is provided (Load Options 2 and 4)
NTRIAL	Not used
NU	Code indicating whether loading is spatially uniform or not: 0-not uniform, 1-uniform
NUSE(NBAR,MBAR)	Use code for the spatial integration stations: 0-not used, 1-not used for printout only, 2-used for integration only, 3-both
NY2	Constant, equal to 3*MGMB
NZP	Not used
OTTO	Constant equal to $1/t_o$, 1/sec (Load Option 3)
OTT1	Constant equal to $1/t_1$, 1/sec (Load Option 3)
P(NGNBT)	Pressure at each spatial point, psi
PB(40)	Not used
PDAM	Not used
*PHI	Angle projectile trajectory makes with the normal to the panel (z-axis), ϕ, degrees (Load Option 1)

PI	Constant, equal to π
PIMA(MBAR)	Constants associated with the equation of motion and Simpson's Rule; Gamma-direction, $in^2/lb\text{-}sec^2$
PINA(NBAR)	Same as PIMA, only in the beta-direction, $in^2/lb\text{-}sec^2$
PPP	Calculated pressure on panel (uniform distributions only), psi
*PP1	Pressure P_1, psi (Load Option 3)
*PPO	Pressure P_0, psi (Load Option 3)
*PRINT	Output frequency - integration steps per printout
PRES(3*MGMB)	Working array in RELAXP, dimensionless
*PRT(NTIME,NPY,NPX)	Pressure specified on panel vs time, psi (Load Option 2)
PRTT(NPY,NPX)	Temporary storage for pressure on panel after interpolation on time, psi (Load Option 2)
*PT(20)	Table of uniform pressures specified on panel, psi (Load Option 4)
PX(3*MGMB)	Working array in RELAXP, dimensionless
Q1	Constant A (Load Option 1)
Q2	Constant B (Load Option 1)
RA(NBAR,MBAR)	Range from detonation point, R, in.
RFR	Not used
RHO	Density of panel, $lb\text{-}sec^2/in^4$

*RHOM(NL)	Density of layer, $lb\text{-}sec^2/in^4$
PR(4)	Reaction force at corners of panel
RRES(3*MGMB)	Working array in RELAXP, dimensionless
RTRIAL(5)	Not used
SAC(NL)	Compressive yield stresses for metal material, compressive ultimate stress for plastic material, psi; not used
SAT(NL)	Tensile yield stress for metal materials, tensile ultimate stress for plastic material, psi; not used
*SIGO	Yield stress for elastic-plastic option, psi
SIGO2	Constant, equal to SIGO squared, lb^2/in^4
SIGTT1(LMAX)	Stress component at time of last yielding, $\sigma_{\theta\theta}$, psi
SIGX(3*MGMB)	Working array in RELAXP, dimensionless
SIGXT1(LMAX)	Stress component at time of last yielding, $\sigma_{x\theta}$, psi
SIGXX1(LMAX)	Stress component at time of last yielding, σ_{xx}, psi
SIGX1S(LMAXST)	Stringer stress component at time of last yielding, σ_{sxx}, psi
SINB(MB*NBAR)	Sines of beta functions, $\sin((n+1)\beta_j)$
SING(MG*MBAR)	Sines of gamma functions, $\sin((m+1)\gamma_i)$
SIN2B(MB*NBAR)	Sines of beta functions, $\sin((n)\beta_j)$
SIN2G(MG*MBAR)	Sines of gamma functions, $\sin((m)\gamma_i)$
STRCN1	Constant for stringer option, $\dfrac{b_s 180}{a\theta_o}$ dimensionless
STRCN2	Constant for stringer option, $\dfrac{b_s h_s 180}{a\pi h\theta_o}$ dimensionless

SMAX	Not used
STT(LMAX)	Stress component, $\sigma_{\theta\theta}$, psi
SXT(LMAX)	Stress component, $\sigma_{x\theta}$, psi
SXX(LMAX)	Stress component, σ_{xx}, psi
SXXSTR(LMAXST)	Stringer stress component, σ_{sxx}, psi
S1A(NGNBT)	Stress component, σ^m_{xx}, psi
S2A(NGNBT)	Stress component, $\sigma^m_{\theta\theta}$, psi
S3A(NGNBT)	Stress component, $\sigma^m_{x\theta}$, psi
S4A(NGNBT)	Stress component, σ^b_{xx}, psi
S5A(NGNBT)	Stress component, $\sigma^b_{\theta\theta}$, psi
S6A(NGNBT)	Stress component, $\sigma^b_{x\theta}$, psi
S7A(NSTR*NBAR)	Stringer stress component, σ^m_{sxx}, psi
S8A(NSTR*NBAR)	Stringer stress component, σ^b_{sxx}, psi
*THETA0	Total angle subtended by cylindrical panel, θ_o, deg, or width of flat panel, b, in.
*THNU(NL)	Poisson's ratio in the theta-direction, ν_θ, dimensionless
*TITLE(20)	Descriptive title of case
TMAX	Not used
*TNU	Poisson's ratio for elastic-plastic option

*TPRIME	Time t' (Load Option 3), sec
*TSTOP	Integration stop time, sec
*TT(20)	Time table (Load Option 4), sec
TTNU(LMAX)	Value of ν_s, dimensionless
TTNUST(LMAXST)	Value of ν_s for stringers, dimensionless
U(NGNBT)	Value of U, dimensionless
UB(NGNBT)	Value of U_β, dimensionless
UG(NGNBT)	Value of U_γ, dimensionless
UU(MB,MG)	Displacement coefficient, U_{mn}, dimensionless
U1(MB,MG)	Displacement coefficients, U_{mn}, representing the static conditions, dimensionless
V(NGNBT)	Value of V, dimensionless
VB(NGNBT)	Value of V_β, dimensionless
VG(NGNBT)	Value of V_γ, dimensionless
VRX(2*NBAR-2)	Normal reactive force per unit length along boundary, V_x, lb/in.
VRT(2*MBAR-2)	Normal reactive force per unit length along boundary, V_θ, lb/in.
VS	Shock velocity, equal to 5.88×10^4 in/sec (Load Option 1)
VV(MB,MG)	Displacement coefficients, V_{mn}, dimensionless
VXO(3*MGMB)	Initial velocity coefficients
V1(MB,MG)	Displacement coefficients, V_{mn}, representing the static conditions, dimensionless
W(NGNBT)	Value of W, dimensionless
WB(NGNBT)	Value of W_β, dimensionless

WBB(NGNBT)	Value of $W_{\beta\beta}$, dimensionless
WBBB(2*MBAR-2)	Value of $W_{\beta\beta\beta}$, dimensionless
WG(NGNBT)	Value of W_{γ}, dimensionless
WGB(NGNBT)	Value of $W_{\gamma\beta}$, dimensionless
WGBB(2*NBAR-2)	Value of $W_{\gamma\beta\beta}$, dimensionless
WGG(NGNBT)	Value of $W_{\gamma\gamma}$, dimensionless
WGGB(2*MBAR-2)	Value of $W_{\gamma\gamma\beta}$, dimensionless
WGGG(2*NBAR-2)	Value of $W_{\gamma\gamma\gamma}$, dimensionless
WW(MB,MG)	Displacement coefficients, W_{mn}, dimensionless
W1(MB,MG)	Displacement coefficients, W_{mn}, representing the static conditions, dimensionless
XB(NBAR)	Integration positions in the beta-direction inches for flat panel, degrees for curved panel
XG(MBAR)	Integration positions in the gamma-direction, inches
XJ	Constant, J. equal to $180/\theta_o$ (dimensionless) for curved panel and π/b (inches) for flat panel
XJ2	Constant, J^2
XJ3	Constant, J/L
XJ4	Constant, 2J
XJ5	Constant, 2J/L
XKTT	Temporary value of strain, $\varepsilon^b_{\theta\theta}$, in/in.
XKXT	Temporary value of strain, $\varepsilon^b_{x\theta}$, in/in.

XKXX	Temporary value of strain, ε^b_{xx}, in/in.
XKXXST	Temporary value of stringer strain, $\varepsilon^b_{s_{xx}}$, in/in.
XL	Constant, ℓ/π, for flat panel (inches), $\ell/\pi a$ for curved panel (dimensionless)
*XLP	Length of panel, ℓ, inches
XLP1	Constant, $2L^2R$
XLP2	Constant, 2LR
XLP3	Constant, $1/2L^2R$
XL1	Constant, 1/L
XL2	Constant, L^2
XL3	Constant, 2/L
XL4	Constant, $2L^2$
XL5	Constant, $2L^2R$
XL7	Constant, $1/L^2$
*XP(NPX)	X-position of pressure-mesh (Load Option 2), in.
XRES(3*MGMB)	Working array in RELAXP, dimensionless
XX(3*MBMG)	Array composed of UU, VV, and WW, dimensionless
*XXNU(NL)	Poisson's ratio in the x-direction, ν_x, dimensionless
XX1(3*MGMB)	Working array in RELAXP, dimensionless
X1A(NGNBT)	Strain component, ε^m_{xx}, in/in.
X2A(NGNBT)	Strain component, $\varepsilon^m_{\theta\theta}$, in/in.
X3A(NGNBT)	Strain component, $\varepsilon^m_{x\theta}$, in/in.

X4A(NGNBT)	Strain component, ε^b_{xx}, in/in.
X5A(NGNBT)	Strain component, $\varepsilon^b_{\theta\theta}$, in/in.
X6A(NGNBT)	Strain component, $\varepsilon^b_{x\theta}$, in/in.
X7A(NSTR*NBAR)	Stringer strain component, ε^m_{sxx}, in/in.
X8A(NSTR*NBAR)	Stringer strain component, ε^b_{sxx}, in/in.
*YP(NPX)	Y-position of pressure-mesh (Load Option 2), in. or deg
YY(3*MGMB)	Array composed of acceleration coefficients, $\ddot{U}_{mn}$, $\ddot{V}_{mn}$, $\ddot{W}_{mn}$, 1/sec^2
ZA(2)	ZB normalized with a, ZB/a, inches for flat plate, dimensionless for a curved panel
ZASTR(2)	ZBSTR normalized with a, ZBSTR/a, inches for flat plate, dimensionless for a curved panel
ZB(2)	± layer thickness/2, in.
ZBSTR(2)	± HSTR/2, in.
ZC(2*NL)	± layer thickness, in.
ZCSTR(2)	± HSTR/2, in.
*ZEE	Distance from panel to detonation, Z, in. (Load Option 1)
ZF(LBAR)	ZH normalized with a, ZH/a, inches for a flat plate, dimensionless for a curved panel
ZFSTR(LGARST)	ZHSTR normalized with a, ZHSTR/a, inches for a flat plate, dimensionless for a curved panel
ZG(LBAR)	Gaussian station squared, ξ_i^2, dimensionless

ZGSTR(LBARST)	Gaussian stringer station squared, ξ_i^2, dimensionless
ZH(LBAR)	z coordinates corresponding to the Gaussian integration points through the panel thickness for the elastic-plastic option, in.
ZHSTR(LBARST)	z coordinates corresponding to the Gaussian integration points through the stringer thickness for the elastic-plastic option, in.
ZZ1(9)	Not used

B.2.4 Program Operation

The DEPROSP program is written in FORTRAN IV and consists of 19 user supplied routines on approximately 3300 cards. The code was developed on the Control Data Corporation (CDC) 6600 computer under the NOSBE1 operating system.

In order to minimize the amount of central memory core required to execute the program, the user should eliminate at least one of two options prior to loading. This choice of options is either the elastic static solution capability, where subroutines RELAXP, LIST1 and SOLVE are required, or the elastic-plastic option where subroutines LIST2 and SIGMA are required. For stringer calculations, the subroutine SOLVE is also needed in the elastic-plastic option. These options are outlined in Tables XII and XIII, and the corresponding program core requirements are given. Elimination of the unnecessary subroutines can be accomplished by removing them from the deck (or file) completely,

replacing them with dummy routines, or using an SLOAD instruction to selectively load the required routines. The use of blank common enables the program to load and execute at the same core level. Input and output are equated with logical files TAPE5 and TAPE6, respectively, and there are no additional tape or disk file requirements for operating the code.

The FTN compiler has been used to compile the code under "OPT=1" and "R=2" options. Compilation requires approximately 80,000 words and 24 seconds CP time.

Computation time will vary considerably, depending on the panel, the complexity of the model, whether or not the solution goes inelastic and the response time requested. A very rough approximation for an inelastic response is 6×10^{-4} CP seconds per mode, per integration grid point, per time step of response, for a non-stringer case.

TABLE XII. CORE REQUIREMENTS FOR MAJOR PROGRAM OPTIONS

Program Response Option	Input Parameters KDS	NDERV	Subroutines Eliminated	Core Required to Load and Execute*
Elastic(Dynamic)	2	1	RELAXP, SOLVE, LIST2, SIGMA	151 K_8
Elastic (Static)	1 or 3	1	LIST2, SIGMA	226 K_8
Elastic-Plastic (Dynamic)	2	2	RELAXP, SOLVE, LIST1	254 K_8
Elastic-Plastic with Stringers (Dynamic)	2	2	RELAXP, LIST1	255 K_8
Static, followed by Elastic-Plastic (Dynamic)	3	2	LIST1	330 K_8

*Code compiled under FTN option 1

TABLE XIII. PANEL RESPONSE OPTIONS

Panel Type (KTYPE)	Response Options (NDERV)
1	1,2
3	1,2*
5	1

*The program forms an equivalent single layer for KTYPE = 3, NDERV = 2

B.3 Program Input Data

Specific instructions are provided in this section to enable the user to provide the necessary card input for the DEPROSP program. These instructions are identical to those of the DEPROP program (18) except for the cases where stiffeners are included. Hopefully the program could be run without the use of Reference (18) but for greater detail the user is referred to that reference. The stiffeners are included only for the single layer and the three related response options of static only, dynamic only, and static followed by dynamic. The stiffener is assumed to have the same mechanical properties, the same boundary conditions, and same stress-strain relations as the single layer for either elastic or elastic-plastic response.

The input data are specified in groups, where each group begins on a separate card. More than one card may be required for a group, however. The variable type and format corresponding to each data group is given in parentheses in the input instruction and is always in fields of 12. For convenience, floating point numbers can be left justified in the field as long as the exponent is right justified. Also, zero values can be replaced by a blank field. Columns 73 through 80 are not used for data and can be used for card identification or other purposes.

All input parameters, where appropriate, should be compared with the maximum dimensions provided for in the program, as delineated in Table X. This is very important since the program does not attempt to check the input for such violations.

Group 1 provides for the execution of several jobs (or cases) in the same run. All subsequent data groups (2 to 23) must be repeated for each case.

The panel type, response option, and debug options are specified in Group 3. It is important to check Table XI to insure the correct sub routines are included to the response option selected. It is suggested that the first debug option (NDBUG=0) be selected.

Group 4 contains the number of modes to be used in the solution and the number of integration points to be used. The accuracy of the solution is based on the degree of convergence of stress and strain quantities. These quantities converge less rapidly than the radial displacement. Also, cases involving a clamped edge condition will converge less rapidly than simply-supported cases. Since both computer time and accuracy increase with more modes and points, a trade-off usually becomes necessary. It has been found that about 25 modes give an acceptable general solution for most panels. But more modes are required for better accuracy in determining edge strain and reaction force quantities for clamped panels.

The actual mode numbers are specified in Groups 5 and 6. The maximum value that the mode numbers can assume in the program is 19. When symmetry is taken in either direction (Group 7), or if the pressure loading is symmetrically oriented, only the odd numbered modes (1, 3, 5, ...) are required in that direction.

Spatially, the desired number of integration points (MBAR and NBAR) for a full panel should be approximately two times the maximum mode number used in that direction, plus three. However, when NBN or MGM is large, this condition may not be satisfied for nonsymmetrical panels, since MBAR and NBAR are dimensioned at 23 in the program (see Table X). For symmetric solutions, MBAR (or NBAR) need only be approximately one-half the value for a full panel since only one-half (or one-quarter) of the panel is actually analyzed in the solution. For a nonsymmetric condition, MBAR (or NBAR) must be an odd number. For an elastic-plastic solution, a minimum of four integration points through the thickness is recommended, and a maximum of six is provided in the program.

Information relating to the use of stringers is specified in Groups 8 through 10. In order to be included in the calculations, the stringer locations must coincide with beta integration points selected in Group 13. It is suggested that the number of integration points through the thickness be at least that for the panel, with a maximum of ten allowed in the program.

In Group 11, the user is given the option of a purely elastic solution, or an elastic-plastic solution. The elastic-plastic option will tend to be slower and require more computer memory. It should be noted that honeycomb panels are reduced to an equivalent single-layered panel for elastic-plastic response. Again, Tables XII and XIII should be consulted to insure the program is compatible with the response option selected.

Groups 12 and 13 provide a mechanism for selecting a maximum of 49 modal combinations from a 13 by 13 combination array (MG=MB=13). Thus, the more significant modal combinations for an optimal solution with respect to accuracy and computer time can be selected and the other combinations eliminated. A general rule of thumb is to eliminate the higher frequency modes which are usually associated with modal combinations having the larger MG+MB values. An example of this would be the selection of MG=MB=7 for a symmetric problem, but eliminating 24 combinations as indicated in Figure 27. The relative importance of each modal combination can be evaluated by examining the response output and comparing the magnitude of the displacement coefficients.

Groups 14 and 15 are responsible for selecting the points in the integration grid for which printout of strains, stresses, displacements, reactive forces (or boundaries), and pressures is

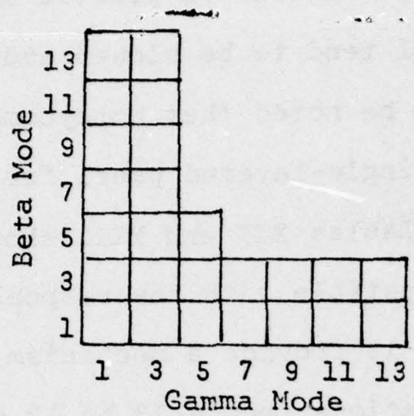

Figure 27. Example of Modal Selection.

required. Strains and stresses are computed at the inner and outer surfaces of the panel Each point in the grid is designated by a pair of integers, the first integer referring to the gamma-position, the second to the beta-position. Actual positions are found from

$$x = \frac{\ell}{2} \frac{(I-1)}{(\overline{M}-1)} \qquad I = 1,\ldots,\overline{M} \quad \text{(symmetric in x-direction)}$$

$$x = \ell \frac{(I-1)}{\overline{M}-1} \qquad I = 1,\ldots,\overline{M} \quad \text{(full in x-direction)}$$

and similar expressions for y (or θ). For example, the corner point in a symmetric panel would be numbered (1,1); the center, (MBAR,NBAR). It is suggested that these points include the stringer locations so that the effect of the stringer on the strains and stresses can be displayed.

Group 23 contains the modal components, δ_{mn}, for the initial radial imperfections. The analyst must compute the δ_{mn}'s from measured data using the integration technique applied to Fourier series coefficients. Generally, such data will not be available, and zero values should be specified for the δ_{mn}'s. The capability of considering initial imperfections also enables the analyst to determine the sensitivity of panel response to initial imperfections.

Group 24 provides the integration time increment, the response stop time, and the printout interval. If the user specifies a zero time increment, the program computes an appropriate Δt which, in most cases, will give a stable solution. Because it is approximate, the analyst may want to make comparable runs using different Δt's. In general, an elastic solution which is numerically stable will be accurate. Hence, the optimum Δt is the largest which remains stable. For an elastic-plastic solution, however, the accuracy of the solution may deteriorate slightly as the point at which the solution diverges is approached. For an elastic-plastic solution with stringers, a smaller Δt may be required. Once a time increment is selected, it should be valid for moderate changes in response level.

Although the stop time can vary a great deal, the total number of integration steps required to capture peak response

will be roughly between 500 to 1500. One exception to this may be a curved panel experiencing snap-through buckling, in which case considerably larger response times may be required. A printout frequency of once every 20 steps is usually adequate for monitoring the response time history.

Groups 25 to 36 provide for the appropriate pressure load on the panel. The user should refer to Figure 16 or 17 for a definition of certain input parameters.

Group 1: (I12) NCASES

Number of cases to be run (NCASES)

Group 2: (20A4) TITLE

Identifying title per run, date, etc. Free field. (TITLE)

Group 3: (3I12) KTYPE, KDS, NDBUG

Code designating panel type (KTYPE)

1, Single-layer panel

3, Honeycomb panel (3 layers)

5, Multilayer panel (elastic response only)

Response option code (KDS)

1, Static only

2, Dynamic only

3, Static, followed by dynamic

Debug option (NDBUG)

0, No debug output

1, Most debug output

2, All debug output

Group 4: (5I12) MG, MB, MBAR, NBAR, LBAR

Number of gamma modes to be used (MG)

Number of beta modes to be used (MB)

Number of gamma integration points actually used over the portion of the panel analyzed. Must be an odd number for full panel (see Group 7) (MBAR)

Number of beta integration points actually used over the portion of the panel analyzed. Must be an odd number for full panel (see Group 7) (NBAR)

Number of z integration points used through the thickness. (LBAR) [Not needed for NDERV=1 (see Group 11)]

Group 5: (6I12) (MGM(I), I=1, MG)

Gamma mode numbers, m

Group 6: (6I12) (NBN(I), I=1, MB)

Beta mode numbers, n

Group 7: (2I12) NSYMG, NSYMB

Symmetry code in gamma direction (NSYMG):

0, Symmetry assumed $(0 \leq \gamma \leq \pi/2)$

1, No symmetry $(0 \leq \gamma \leq \pi)$

Symmetry code in beta direction (NSYMB):

0, Symmetry assumed $(0 \leq \beta \leq \pi/2)$

1, No symmetry $(0 \leq \beta \leq \pi)$

Group 8: (2I12) MBSTR, LBARST

Number of stringers to be considered (MBSTR)

Number of z integration points used through the stringer thickness (LBARST) [Not needed for NDERV=1 (see Group 11)]

If MBSTR=0, skip to Group 11.

Group 9: (2F12.1) BSTR, HSTR

Width of stringers, in. (BSTR)

Thickness of stringers, in. (HSTR)

Group 10: (6I12) (LOCSTR(I), I=1, MBSTR), if NYSMB=1 or (LOCSTR(I), I=1 , (MBSTR+1)/2), if NYSMB=0

Position of stringers. Must coincide with beta integration points actually used (LOCSTR)

Group 11: (3I12) NPLT, NBND, NDERV

Panel type (NPLT):

0, Flat panel

1, Cylindrical panel

Boundary condition code (NBND)

	γ-direction	β-direction
1,	Clamped-clamped;	Clamped-clamped
2,	Simple-simple;	Simple-simple

3, Clamped-clamped; Simple-simple

4, Simple-simple; Clamped-clamped

5, Clamped-simple; Clamped-clamped

6, Clamped-clamped; Clamped-simple

7, Clamped-simple; Simple-simple

8, Simple-simple; Clamped-simple

9, Clamped-simple; Clamped-simple

Note: Whenever a clamped-simple condition is selected, the full panel is analyzed in that direction, and NSYMG, NSYMB, MBAR and NBAR should reflect this.

Response option (NDERV):

1, Elastic only

2, Elastic-plastic

Group 12: (I12) NNOUT

Number of modal combinations to be eliminated from solution (NNOUT).

(0 ≤ NNOUT < MG*MB)

If NNOUT=0, skip to Group 14.

Group 13: (2I12) MOUT(I), NOUT(I)

Gamma mode. (MOUT(I))

Beta mode. (NOUT(I))

Repeat Group 13 for I=1, NNOUT. The cards in Group 13 may be arranged in any order.

Group 14: (I12) NKP

Number of spatial points at which printout of stresses, strains, displacements, reactive forces and pressures are requested. If NKP=0, all of the above information will be suppressed. (NKP)

<u>If NKP=0, skip to Group 16.</u>

Group 15: (2I12) KPG(I), KPB(I)

Integration point in gamma-direction at which printout is requested. Points are ordered 1-MBAR, beginning at $\gamma=0$, and evenly spaced from there. (KPG(I))

Integration point in beta-direction at which printout is requested. Points are ordered 1-NBAR, beginning at $\beta=0$, and evenly spaced from there. (KPB(I))

Note: These two indices are taken as pairs where each pair designates a particular spatial point. The pairs may be specified in any order.

<u>Repeat Group 15 for I=1, NKP.</u>

Group 16: (I12) NL

Number of layers. (NL)

(NL must be 1 for KTYPE=1, and 3 for KTYPE=3)

Group 17: (3F12.1) XLP, THETA0, A

Full length of panel, ℓ, in. (XLP)

Full width of flat panel, b (short direction), in. (NPLT=0)

or

Full subtended angle of cylindrical panel, θ_0, deg. (NPLT=1)

(THETA0)

Radius of cylindrical panel, in. (A)

(Not needed for NPLT=0)

<u>If NDERV=2, skip to Group 21.</u>

Group 18: (2F12.1) HM(I), RHOM(I)

Distance (h) from inner panel surface to the outer surface of layer I, in. (HM(I))

Mass density of layer I, lb-sec^2/in^4. (RHOM(I))

Group 19: (5F12.1) EX(I), ET(I), XXNU(I), THNU(I), GXT(I)

Modulus of elasticity in the x-direction, psi. (EX(I))

Modulus of elasticity in the theta-direction, psi. (ET(I))

Poisson's ratio in the x-direction. (XXNU(I))

Poisson's ratio in the theta-direction. (THNU(I))

Shear modulus, psi. (GXT(I))

Group 20. (2F12.1) SAT(I), SAC(I)

Tensile yield stress for metal panels; tensile ultimate stress for plastic panels, psi. (SAT(I))

Absolute value of compressive yield stress for metal panels; absolute value of compressive ultimate stress for plastic panels, psi. (SAC(I))

<u>Repeat Groups 18-20 for I=1, NL.</u>

<u>Skip to Group 23.</u>

Group 21: (3F12.1) HM(I), RHOM(I), EM(I)

Distance (h) from inner shell surface in the outer surface of layer I, in. (HM(I))

Mass density of layer I, $lb/sec^2/in^4$. (RHOM(I))

Modulus of elasticity, psi. (EM(I))

<u>Repeat Group 21 for I=1, NL.</u>

Group 22: (4F12.1) TNU, SIGO, EP, EPSIF

Poisson's ratio. (TNU)

Yield stress for a metal panel, psi. (SIGO)

Strain hardening modulus (E_t), psi. (EP)

Ultimate strain, in/in. (EPSIF) (not necessary)

Group 23: (6F12.1) ((FG(N,M), N=1,MB), M=1,MG)

Modal displacement coefficients for initial radial imperfections, in. (FG(N,M))

Group 24: (3F12.1) DELTIM, TSTOP, PRINT

Integration time increment, sec. If DELTIM=0.0, the program determines the time increment required for stability. (DELTIM)

Integration stop time, sec. (TSTOP)

Print frequency (integration steps per printout). If PRINT=0.0, printout of intermediate data will be suppressed. (PRINT)

<u>If KDS=2, skip Group 25.</u>

Group 25: (F12.1) PS

Uniform static pressure load, psi. Can be either positive or negative value.

<u>If KDS=1, skip Groups 26-36.</u>

Group 26: (I12) NLOAD

Dynamic load option

1, Special Eglin analytical function over space and time. (See Figure 16)

2, Discrete point by point, time by time distribution

3, Spatially uniform, with an analytical function for time history. (See Figure 17)

4, Spatially uniform, with a discrete time history.

If NLOAD=2, skip to Group 28.

If NLOAD=3, skip to Group 34.

If NLOAD=4, skip to Group 35.

Group 27: (2F12.1) ZEE, PHI

Distance of detonation from panel, Z, in. (ZEE)

Angle projectile trajectory makes with the normal to the panel (z-axis), ϕ, degrees. (PHI)

Skip Groups 28-36.

Group 28: (3I12) NPX, NPY, NTIME

Number of spatial points in the gamma-direction at which pressures are to be specified. (NPX) (Must be at least 2)

Number of spatial points in the beta-direction at which pressures are to be specified. (NPY) (Must be at least 2)

Number of times specified in the pressure-time history. (NTIME) ($2 \leq$ NTIME ≤ 6)

Group 29: (F12.1) DTIM

Time interval between samplings (DTIM). The time history for each point has the same time interval, but distinct delay times (Group 32)

Note: Be sure to allow for first point to be engulfed at time=0. Program will extropolate data past last time in table.

Group 30: (6F12.1) (XP(I), I=1, NPX)

x-positions at which time histories are specified, in. (XP)

Group 31: (6F12.1) (YP(I), I=1, NPY)

y-positions at which time histories are specified, in. (YP)

Group 32: (6F12.1) (DET(J,I), J=1, NPY)

Delay time for pressure wave to reach grid point, sec (DET) (One point must have delay time of zero)

Repeat Group 32 for I=1, NPX.

Group 33: (6F12.1) (PRT(K,J,I), K=1, NTIME)

Pressure for each time and grid point, psi (PRT).

Repeat Group 33 for J=1, NPY.

Repeat Group 33 again, for I=1, NPX.

Skip Groups 34-36.

Group 34: (6I12) PP1, PP0, TT0, TPRIME, AA, ANN

Pressure, p_1, psi (PP1)

Pressure, p_0, psi (PP0)

Time, t_0, sec (TT0)

Time, t', sec (TPRIME)

Parameter a, dimensionless (AA)

Parameter n, dimensionless (ANN)

Note: See Figure 17 for definitions.

Skip Groups 35 and 36.

Group 35: (I12) NTIME

Number of points to be specified in point-by-point load description. (NTIME)

$(2 \leq NTIME \leq 20)$

Note: Be sure to include time=0 and also an end time which exceeds TSTOP. Otherwise, the last value in the table will be used.

Group 36: (2F12.1) TT(I), PT(I)

Time, sec. (TT(I))

Pressure, psi. (PT(I))

Note: One time and one pressure per card.

Repeat Group 36 for I=1, NTIME.

Repeat Groups 2 to 36 for each additional case, as specified in Group 1.

B.4 Program Output

The output for DEPROSP is directed to the printer. Although program output is largely self-explanatory, the normal output is described in detail in Table XIV. Where possible, the corresponding program variable is given parenthetically.

Certain errors, if detected by the program during execution, are brought to the user's attention by means of a printed error message. Table XV provides a list of such messages, along with an indication of the routine associated with the message and the subsequent action the program takes. In most cases, the program will cycle back to attempt the next case if it cannot continue with the current one.

TABLE XIV. DEPROSP STRUCTURAL RESPONSE OUTPUT

Time-History Output

Time from shock arrival, sec (TIME)

Normalized axial, tangential, and radial displacement modal coefficients for all modes, with the beta mode index varying most rapidly ((UU(J,I), VV(J,I), WW(J,I), J=1,MB),I=1,MG)

Table of stress-strain information for inner and outer surfaces at each grid point selected:

Flag ("S") indicating stringer portion of stress and strain
X coordinate, in. (XG)
Beta position, in. or deg (XB)
Depthwise position, in.
Axial strain, dimensionless
Circumferential strain, dimensionless
Shearing strain, dimensionless
Axial stress, lb/in^2
Circumferential stress, lb/in^2
Shearing stress, lb/in^2
Flag ("*") indicating equivalent strain has exceeded yield strain (elastic runs only)
Counter indicating number of unloading and reyielding (KY) (elastic-plastic runs only)

Table of reactive force information for each grid point selected:

Normal reactive force (V_x or V_θ), lb/in.
(VRX or VRT)

Tangential reactive force (N_x or N_θ), lb/in.
(ENX or ENT)

Reactive forces at corners:

Reactive force (R), lb
(omitted for panels clamped on all edges since forces are all zero).

Table of displacement-pressure information at each grid point selected:

X-coordinate, in (XG)
Beta-position, in or deg (XB)
Axial displacement, in (UF)

TABLE XIV. (Concluded)

Tangential displacement, in (VF)
Radial displacement, in (WF)
Pressure, psi (PPP)

Summary Output

Message indicating whether run was terminated normally or abnormally, and the time at which computations stopped, sec (TIME)

Net CP time for response, sec (CPT)

Number of integration points which yielded, if any (Elastic-plastic response only)

TABLE XV. ERROR MESSAGES

CANNOT TOTALLY CORRECT FOR OVERSHOOT. XXX (PANEL or STRINGER).

An iterative process to correct for overshoot associated with yielding has not converged in five trials. This probably means a numerical instability is creeping into the solution. Program continues until such errors occur 100 times. (SIGMA)

DEPROSP IS ABORTED AT T, SEC = XXX.

DEPROSP cycles back to attempt next case. This case is aborted. (DEPROSP)

EPP IS OUT OF RANGE (PANEL or STRINGER).

Numerical instability detected. A smaller Δt may be required. This case is aborted. (SIGMA)

IMMEDIATE RELOADING, XXX (PANEL or STRINGER).

Probable numerical instability creeping into solution. Program continues until such errors occur 100 times. (SIGMA)

SINGULAR MATRIX IN S/R SOLVE.

The relaxation process has generated a singular matrix in determining static equilibrium or a singular matrix has been generated during a stringer solution of the equations of the 2nd order differential equations of the axial or radial displacement components as in Eq. (33). Program aborts this case. (SOLVE)

SOLUTION DIVERGING IN DEPROSP

Very large accelerations have been computed in DERV2, indicating a numerical instability. A smaller Δt may be required. This case is aborted. (DERV2)

SOLUTION DIVERGING IN RELAXP.

The iterative process to find static equilibrium has failed. Program aborts this case. (RELAXP)

SOLUTION IS UNSTABLE.

Numerical instability has been detected in elastic-plastic solution. A smaller Δt is required. This case is aborted. (SIGMA)

TABLE XV. (Concluded)

STRINGER CALCULATION.

This message precedes another error message signaling that the problem was encountered while calculating a stringer stress or strain. (SIGMA)

THE VALUE OF LBAR IS INVALID. LBAR = XXX.

An incorrect value of LBAR has been specified. This case is aborted. (LEGEND)

THE VALUE OF LBARST IS INVALID. LBARST = XXX.

An incorrect value of LBARST has been specified. This case is aborted. (LEGEND)

TOO MANY TRIALS IN STATIC SOLUTION. MTR = XXX.

To avoid looping indefinitely in attempting a solution representing static equilibrium, an upper limit of 10 is placed on the number of trials. Program may need more trials and adjustment of the variable CON in RELAXP. Program cycles to next case. (DEPROSP)

WARNINGINCONSISTENCY IN SYMMETRY

A clamped-simple boundary condition has been specified, while a symmetric solution has been indicated. Program continues. (DSET3)

WARNING - TIME EXCEEDS TABLE

Either TSTOP should be reduced or the time-pressure table extended. Program uses last value in table and continues. (Load Option 4)

B.5 Program Listing (DEPROSP)

```
      PROGRAM DEPROSP (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      COMMON /FIRST/ ICOUNT
      COMMON/CNOVA/   CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1   KDAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NDBUG,NMASS,NTRIAL,
     2  PB(40),PDAM,PPP,PRINT,RER,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3   ZZ1(9)
      COMMON /CLOAD/ PP1,PPO,TTC,TPRIME,AA,ANN,OTT1,OTTO,AZ,
     1  JL,NTIME,NLOAD,PT(20),TT(20), ZEE,PHI,Q1,Q2,VS,
     2  DET(10,10),NPX,NPY,DTIM,PRT(6,10,10),XP(10),YP(10),
     3  IXI(23),JYJ(23),JLT(10,10),PRTT(10,10),DX1(23),DY1(23)

    1 FORMAT(6I12)
    2 FORMAT(6F12.1)
    3 FORMAT (20A4)
      NCASE = 0
      INOUT = 1
      ICOMP = 5
      ICOUNT = 37777000000000000003B
      READ (5,1) NCASES
  100 READ (5,3) (TITLE(I),I=1,20)
      NCASE = NCASE + 1
      KERR = 0
      NTRIAL = 0
      KDAM = 2
      READ (5,1) KTYPE,KDS,NDBUG
      IF (INOUT.EQ.0) GO TO 1400
      WRITE(6,3000) (TITLE(I),I=1,20)
      GO TO (300,400,500,600,700), KTYPE
  300 WRITE(6,3500)
      GO TO 1050
  400 WRITE(6,3600)
      GO TO 1050
  500 WRITE(6,3700)
      GO TO 1050
  600 WRITE(6,3800)
      GO TO 1050
  700 WRITE(6,3900)
      GO TO 1050
 1050 GO TO (1100,1200,1300), KDS
 1100 WRITE(6,4300)
      GO TO 1400
 1200 WRITE(6,4400)
      GO TO 1400
 1300 WRITE(6,4500)
 1400 NCALL = 2
      CALL PROP
      IF (KERR.GT.0) GO TO 1600
      NCALL = 1
      CALL PINIT(0)
      CALL PROP
      IF (KDS.EQ.1) GO TO 1600
```

```
      IF (KERR.GT.0) GO TO 1600
      NCALL = 0
      KOK = 0
      CALL PINIT(1)
      RTRIAL(1)=1.0
 1500 NTRIAL = NTRIAL + 1
      CALL PROP
 1600 IF (NCASE.LT.NCASES) GO TO 100
 1700 STOP
C
 3000 FORMAT (1H1,30X,13HD E P R O S P//1X,20A4)
 3500 FORMAT (28H0SINGLE-LAYER METAL PANEL    )
 3600 FORMAT (30H0SINGLE-LAYER PLASTIC PANEL    )
 3700 FORMAT (25H0HONEYCOMB METAL PANEL    )
 3800 FORMAT (27H0HONEYCOMB PLASTIC PANEL    )
 3900 FORMAT (29H0MULTI-LAYER PLASTIC PANEL    )
 4300 FORMAT (21H0STATIC SOLUTION ONLY)
 4400 FORMAT (22H0DYNAMIC RESPONSE ONLY)
 4500 FORMAT (37H0STATIC SOLUTION AND DYNAMIC RESPONSE)
      END
```

```
      SUBROUTINE BOLT
C
C     THIS SUBROUTINE SETS UP W MODE SHAPES FOR BOUNDARY CONDITIONS
C       SELECTED.
C
      COMMON/CBLK1/   A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1    MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2    NBND,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK2/   BETR(23),CC1(13),CC2(13),CC5(13),CC6(13),
     1    CK(6),COSB(299),COSG(299),COS2B(299),COS2G(299),DPRT,DPRT1,
     2    FP1(299),FP2(299),FP3(299),FP4(13,2),FP5(299),FP6(299),
     3    FP7(299),FP8(13,2),
     3    GAM(23),KC,PIMA(23),PINA(23),SINB(299),SING(299),
     4    SIN2B(299),SIN2G(299),XJ,XJ2,XJ3,XJ4,XJ5,XL,XLP,XLP1,XLP2,
     5    XLP3,XL1,XL2,XL3,XL4,XL5,XL7,STRCN1,STRCN2
      DIMENSION CD1(20),CD2(20),CD3(20),CD4(20)
      DIMENSION CDL(20), CDA(20)
      DATA CD1/1.5056187314,2.49975267005,3.50001067945,4.49999953847,
     1  5.50000001994,6.49999999915,7.5,8.5,9.5,10.5,11.5,12.5,13.5,
     2  14.5,15.5,16.5,17.5,18.5,19.5,20.5/
      DATA CD2/0.982502214568,1.00077731189,0.999966450124,
     1  1.00000144989,0.999999937336,1.00000000270,0.999999999881,
     2  13*1.0/
      DATA CD3/1.24987633505,2.24999976925,3.24999999959,4.25,5.25,6.25,
     1  7.25,8.25,9.25,10.25,11.25,12.25,13.25,14.25,15.25,16.25,
     2  17.25,18.25,19.25,20.25/
      DATA CD4/1.00077731192,1.00000144989,1.00000000269,17*1.0/
C
C
      FAC = SQRT(2.0)
      DO 100 I=1,4
  100 CK(I) = FAC
      II = 0
      GO TO (500,700,500,700,900,500,900,700,900), NBND
C
C     CLAMPED - CLAMPED, GAMMA.
C
  500 DO 520 I=1,MG
      M = MGM(I)
      CDL(I) = CD1(M)
  520 CDA(I) = CD2(M)
  540 DO 600  M=1,MG
      X1 = CDL(M)
      X2 = CDA(M)
      DO 600 I=1,NGT
      II = II + 1
      X3 = X1*GAM(I)
      EX1 = EXP(X3)
      EX2 = EXP(-X3)
      SL = SIN(X3)
      CL = COS(X3)
```

```
      FP1(II) = -CL + X2*SL + .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1
      FP2(II) = X1*(SL + X2*CL - .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1)
      FP3(II) = X1**2*(CL - X2*SL + .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1)
      IF (I.EQ.1) FP4( M,1) = -2.0*X2*X1**3
      IF (I.EQ.MBAR) FP4( M,2) = X1**3*(-SL - X2*CL + .5*((1. - X2)*
     1 EX1 - (1. + X2)*EX2))
  600 CONTINUE
      CK(5) = 1./FAC
      GO TO 1000
C
C     SIMPLY - SIMPLY, GAMMA.
C
  700 DO 800 M=1,MG
      X1 = MGM(M)
      DO 800 I=1,NGT
      II = II + 1
      X2 = X1*GAM(I)
      X3 = SIN(X2)
      FP1(II) = X3
      FP2(II) = X1*COS(X2)
      FP3(II) = -X1**2*X3
      IF (I.EQ.1) FP4(M,1) = -X1**3
      IF (I.EQ.MBAR) FP4(M,2) = -X1**3*COS(X2)
  800 CONTINUE
      CK(5) = FAC
      GO TO 1000
C
C     CLAMPED - SIMPLY, GAMMA.
  900 DO 920 I=1,MG
      M = MGM(I)
      CDL(I) = CD3(M)
  920 CDA(I) = CD4(M)
      GO TO 540
C
C
 1000 II = 0
      GO TO (1100,1300,1300,1100,1100,1500,1300,1500,1500), NBND
C
C     CLAMPED - CLAMPED, BETA.
C
 1100 DO 1120 I=1,MB
      N = NBN(I)
      CDL(I) = CD1(N)
 1120 CDA(I) = CD2(N)
 1140 DO 1200  N=1,MB
      X1 = CDL(N)
      X2 = CDA(N)
      DO 1200 J=1,NBT
      II = II + 1
      X3 = X1*BETP(J)
      EX1 = EXP(X3)
```

```
      EX2 = EXP(-X3)
      SL = SIN(X3)
      CL = COS(X3)
      FP5(II) = -CL + X2*SL + .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1
      FP6(II) = X1*(SL + X2*CL - .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1)
      FP7(II) = X1**2*(CL - X2*SL + .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1)
      IF (J.EQ.1) FP8( N,1) = -2.0*X2*X1**3
      IF (J.EQ.NBAR) FP8( N,2) = X1**3*(-SL - X2*CL + .5*((1. - X2)*
     1  EX1 - (1. + X2)*EX2))
 1200 CONTINUE
      CK(6) = 1./FAC
      GO TO 1600
C
C     SIMPLY - SIMPLY, BETA.
C
 1300 DO 1400 N=1,MB
      X1 = NBV(N)
      DO 1400 J=1,NBT
      II = II + 1
      X2 = X1*BETR(J)
      X3 = SIN(X2)
      FP5(II) = X3
      FP6(II) = X1*COS(X2)
      FP7(II) = -X1**2*X3
      IF (J.EQ.1) FP8(N,1) = -X1**3
      IF (J.EQ.NBAR) FP8(N,2) = -X1**3*COS(X2)
 1400 CONTINUE
      CK(6) = FAC
      GO TO 1600
C
C     CLAMPED - SIMPLE, BETA.
 1500 DO 1520 I=1,MB
      N = NBN(I)
      CDL(I) = CD3(N)
 1520 CDA(I) = CD4(N)
      GO TO 1140
C
 1600 RETURN
      END
```

```
      SUBROUTINE DERV2
C
      COMMON/CBLK1/  A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1   MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2   NBND,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK2/  BETR(23),CC1(13),CC2(13),CC5(13),CC6(13),
     1   CK(6),COSB(299),COSG(299),COS2B(299),COS2G(299),DPRT,DPRT1,
     2   FP1(299),FP2(299),FP3(299),FP4(13,2),FP5(299),FP6(299),
     3   FP7(299),FP8(13,2),
     3   GAM(23),KC,PIMA(23),PINA(23),SINB(299),SING(299),
     4   SIN2B(299),SIN2G(299),XJ,XJ2,XJ3,XJ4,XJ5,XL,XLP,XLP1,XLP2,
     5   XLP3,XL1,XL2,XL3,XL4,XL5,XL7,STRCN1,STRCN2
      COMMON/CBLK3/  GX(6),GXSTR(14),HGO(6),HGOSTR(14)
      COMMON/CBLK4/  NY2,VXO(147),XX(147),YY(147),
     1   AAU(49,49),AAW(49,49),BBU(49),BBW(49),IPJ(49),IPW(49)
      COMMON/CBLK8/  NU,P(361),PA(23,23)
      COMMON/CBLK10/ DWB(361),DWG(361),DWO(361),          U(361),
     1   UB(361),UG(361),V(361),VB(361),VG(361),W(361),WB(361),
     2   WBB(361),WG(361),WGB(361),WGG(361)
      COMMON/CBLK11/ CM11,CM11ST,CM12,CM22,CM33,DM11,DM11ST,DM12,DM22,
     1   DM33,FM11,FM12,FM22,FM33
      COMMON /CBLK14/ NBUSE(23,23),NRC,C1,C2,C3,C4,C5,C6,C7,
     1  DELX,DELT,    WGGG(44),WBBB(44),WGGB(44),WGBB(44),
     2  VRX(44),VRT(44),RR(4),ENX(44),ENT(44),NKP,KPG(46),KPB(46)
      COMMON/CNOVA/  CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1   KDAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NDBUG,NMASS,NTRIAL,
     2  PB(40),PDAM,PPP,PRINT,RFR,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3   ZZ1(9)
      COMMON         CN10,CN11,CN8,CN9,EPBO(1805),EPBOST(1380),ETT,EXT,
     1   EXX,EXXSTR,INZ(2),INZSTR(2),KSUMA(361),KSUMAS(231),KY(1805),
     2   KYSTR(1380),NUSE(23,23),STT(1805),SXT(1805),SXX(1805),
     3   SXXSTR(1380),S1A(361),S2A(361),S3A(361),S4A(361),S5A(361),
     4   S6A(361),S7A(230),S8A(230),UU(13,13),VV(13,13),WW(13,13),
     5   XB(23),XG(23),XKTT,XKXT,XKXX,XKXXST,X1A(361),X2A(361),X3A(361),
     6   X4A(361),X5A(361),X6A(361),X7A(230),X8A(230),ZA(2),ZASTR(2),
     7   ZB(2),ZBSTR(2),ZF(6),ZFSTR(14),ZG(6),ZGSTR(14),ZH(6),ZHSTR(14)
C
      IF (NCALL.EQ.0) CALL PRESS
C
      I=1
      DO 100 M=1,MG
      DO 100 N=1,MB
      IF (MUSE(N,M).EQ.0) GO TO 100
      UU(N,M)=XX(I)
      VV(N,M)=XX(MGMB+I)
      WW(N,M)= XX(MGMB2+I)
      I=I+1
  100 CONTINUE
      K=0
      DO 500 I=1,NGT
      II = 0
```

```
IF (I.EQ.1) II = 1
IF (I.EQ.MBAR.AND.NSYMG.EQ.1) II = 2
DO 500 J=1,NBT
IF (NUSE(J,I).EQ.0) GO TO 500
NBC = NBUSE(J,I)
JJ = 0
IF (J.EQ.1) JJ = 1
IF (J.EQ.NBAR.AND.NSYMB.EQ.1) JJ = 2
K=K+1
SS1=0.0
SS2=0.0
SS3=0.0
SS4=0.0
SS5=0.0
SS6=0.0
SS7=0.0
SS8=0.0
SS9=0.0
SS10=0.0
SS11=0.0
SS12=0.0
SS13 = 0.
SS14 = 0.
SS15 = 0.
SS16 = 0.
DO 400 M=1,MG
MM= (M-1)*NGT+I
SM=SING(MM)
CM=COSG(MM)
SM2=SIN2G(MM)
CM2=COS2G(MM)
T1 = FP1(MM)
T2 = FP2(MM)
T3 = FP3(MM)
T4 = 0.
IF (II.GT.0) T4 = FP4(M,II)
S1=0.0
S3=0.0
S4=0.0
S6=0.0
S7=0.0
S9=0.0
S11=0.0
S14 = 0.
DO 200 N=1,MB
IF (MUSE(N,M).EQ.0) GO TO 200
NN= (N-1)*NBT+J
T5 = 0.
IF (JJ.GT.0) T5 = FP8(N,JJ)
SN=SINB(NN)
CN=COSB(NN)
```

```
      SN2=SIN2B(NN)
      CN2=COS2B(NN)
      UMN=UU(N,M)
      VMN=VV(N,M)
      WMN=WW(N,M)
      S1=S1+UMN*SN2
      S3=S3+CC2(N)*UMN*CN2
      S4=S4+VMN*SN
      S6=S6+CC6(N)*VMN*CN
      S7 = WMN*FP5(NN) + S7
      S9 = WMN*FP6(NN) + S9
      S11 = WMN*FP7(NN) + S11
      S14 = WMN*T5 + S14
  200 CONTINUE
      SS1=S1*SM+SS1
      SS2=S1*CC5(M)*CM + SS2
      SS3=S3*SM + SS3
      SS4=S4*SM2+SS4
      SS5=S4*CC1(M)*CM2+SS5
      SS6=S6*SM2+SS6
      SS7 = S7*T1 + SS7
      SS8 = S7*T2 + SS8
      SS9 = S9*T1 + SS9
      SS10 = S7*T3 + SS10
      SS11 = S11*T1 + SS11
      SS12 = S9*T2 + SS12
      IF (NBC.EQ.0.OR.NBC.GT.100) GO TO 400
      SS13 = S7*T4 + SS13
      SS14 = S14*T1 + SS14
      SS15 = S11*T2 + SS15
      SS16 = S9*T3 + SS15
  400 CONTINUE
      U(K)=SS1
      UG(K)=SS2
      UB(K)=SS3
      V(K)=SS4
      VG(K)=SS5
      VB(K)=SS6
      W(K)=SS7
      WG(K)=SS8
      WB(K)=SS9
      WGG(K)=SS10
      WBB(K)=SS11
      WGB(K)=SS12
      IF (NBC.EQ.0.OR.NBC.GT.100) GO TO 500
      NBC = IABS(NBC)
      IF (II.EQ.0) GO TO 450
      WGGG(NBC) = SS13
      WGBB(NBC) = SS15
      GO TO 500
  450 WBBB(NBC) = SS14
```

```
      WGSP(NPC) = SS16
 500  CONTINUE
C
C  COMPUTE STRAINS AND STRESSES
C
      K=0
      KSTR=0
      DO 700 I=1,NGT
      DO 700 J=1,NBT
      IF (NUSE(J,I).EQ.0) GO TO 700
      K=K+1
      IMASTR=0
      IF (NSTR.EQ.0)  GO TO 550
      DO 510  LSTR=1,NSTR
      IF (LOCSTR(LSTR).NE.J) GO TO 510
      IMASTR=1
      KSTR=KSTR+1
 510  CONTINUE
 550  UF=U(K)
      UGF=UG(K)
      UBF=UB(K)
      VF=V(K)
      VGF=VG(K)
      VBF=VB(K)
      WF=W(K)
      WGF=WG(K)
      WBF=WB(K)
      DWGF=DWG(K)
      DWBF=DWB(K)
      EXX=XL1*(UGF+XL1*(WGF*DWGF+0.5*(WGF**2+VGF**2+UGF**2)))
      ETT=XJ*(VBF+XJ*(WBF*DWBF+0.5*(WBF**2+VBF**2+UBF**2)))
      EXT=XJ*UBF+XL1*(VGF*(1.0+XJ*VBF)+XJ*(WGF*(WBF+DWBF)+DWGF*WBF+UBF*
     1UGF))
      AC = XJ*VBF + XL1*UGF + 1.0
      WGGF = WGG(K)
      WBBF = WBB(K)
      WGBF = WGB(K)
      XKXX = XL7*WGGF*AC
      XKTT = XJ2*WBBF*AC
      XKXT = XJ5*WGBF*AC
      IF (IMASTR.EQ.0) GO TO 580
      EXXSTR = EXX - (XL1**2*0.5*VGF**2)
      XKXXST = XKXX - XL7*WGGF*XJ*VBF
 580  IF (NPLT.EQ.0) GO TO 600
      ETT=ETT-WF*(1.0+XJ*VBF-0.5*WF)+VF*(XJ*WBF+0.5*VF)
      EXT =EXT+XL1*(WGF*VF-VGF*WF)
      XKTT=XKTT+XJ5*VBF+XL1*UGF-WF
      XKXT=XKXT+XL1*VGF
      AC = XJ*WBF + VF
      XKXX = XKXX - XL7*WGGF*WF
      IF (IMASTR.NE.0) XKXXST = XKXXST - XL7*WGGF*WF
```

```
      XKTT = XKTT + XJ*VBF*(XJ*VBF - WF) - XJ2*WF*WBBF +
     1  (XJ*VBF - WF)**2 + AC*(AC + XJ*WBF)
      XKXT = XKXT - XJ5*WGBF*WF + XL3*WGF*AC
  600 IF (NDERV.EQ.2) GO TO 640
      S1A(K) = DM11*EXX + DM12*ETT + FM11*XKXX + FM12*XKTT
      S2A(K) = DM22*ETT + DM12*EXX + FM22*XKTT + FM12*XKXX
      S3A(K) = DM33*EXT + FM33*XKXT
      S4A(K)  = DM11*XKXX + DM12*XKTT + FM11*EXX + FM12*ETT
      S5A(K)  = DM22*XKTT + DM12*XKXX + FM22*ETT + FM12*EXX
      S6A(K)  = DM33*XKXT + FM33*EXT
      IF (IMASTR.EQ.0) GO TO 660
      S7A(KSTR)= DM11ST*EXXSTR
      S8A(KSTR)= DM11ST*XKXXST
      GO TO 660
  640 CALL SIGMA (J,I,K,KSTR)
  660 X1A(K) = EXX
      X2A(K) = ETT
      X3A(K) = EXT
      X4A(K) = XKXX
      X5A(K) = XKTT
      X6A(K) = XKXT
      IF (IMASTR.EQ.0) GO TO 700
      X7A(KSTR) = EXXSTR
      X8A(KSTR) = XKXXST
  700 CONTINUE
      IF (KERR.GT.0) GO TO 2200
C
      K = 0
      KSTR = 0
      DO 750 I=1,NGT
      DO 750 J=1,NBT
      IF (NUSE(J,I).EQ.0) GO TO 750
      K = K + 1
      IMASTR = 0
      IF (NSTR.EQ.0) GO TO 740
      DO 725  LSTR=1,NSTR
      IF (LOCSTR(LSTR).NE.J) GO TO 725
      IMASTR = 1
      KSTR = KSTR + 1
  725 CONTINUE
  740 IF (NBUSE(J,I).NE.0) CALL REIT(I,J,K,KSTR)
  750 CONTINUE
C
      IF (NCALL.EQ.1) GO TO 900
      KZ=0
      IF (KDAM.LT.2.AND.KC.EQ.10) KZ = 1
      IF (PRINT.EQ.0.) GO TO 800
      IF (TIME.LT.DPRT) GO TO 800
      KZ=KZ+2
      IF (KDAM.LT.2) KZ = 3
      DPRT=DPRT+DPRT1
```

```
C     PRINT RESULTS AND/OR CHECK MAXIMUMS
  800 IF (NDERV.EQ.1) CALL LIST1
      IF (NDERV.EQ.2) CALL LIST2
      IF (KZ.EQ.1.OR.KZ.EQ.3) KC = 0
      KC = KC + 1
C
C
  900 IZ=0
      DO 910  IR=1,49
      BBU(IR)=0.0
      BBW(IR)=0.0
      DO 910  IS=1,49
      AAU(IR,IS)=0.0
  910 AAW(IR,IS)=0.0
      DO 2000 IR=1,MG
      MMO=(IR-1)*NGT
      DO 2000 IS=1,MB
      IF (MUSE(IS,IR).EQ.0) GO TO 2000
      NNO=(IS-1)*NBT
      IZ=IZ+1
      SURS=0.0
      SVRS=0.0
      SWRS=0.0
      SURSST=0.0
      SWRSST=0.0
      K=0
      KSTR=0
      DO 1700 I=1,NGT
      MM=MMO+I
      SM=SING(MM)
      CM=COSG(MM)
      SM2=SIN2G(MM)
      CM2=COS2G(MM)
      T1 = FP1(MM)
      T2 = FP2(MM)
      T3 = FP3(MM)
      SU = 0.
      SV = 0.
      SW = 0.
      SUSTR=0.0
      SWSTR=0.0
      PRLM = PTMA(I)
      DO 1600 J=1,NBT
      IF (NUSE(J,I).EQ.0) GO TO 1600
      K = K + 1
      IF (NUSE(J,I).EQ.1) GO TO 1600
      IMASTR=0
      IF (NSTR.EQ.0) GO TO 1000
      DO 920  L=1,NSTR
      IF (LOCSTR(L).NE.J) GO TO 920
      IMASTR=1
```

```
      KSTR=KSTR+1
 920  CONTINUE
C
 1000 PRLN = PINA(J)
      PRLNST = STRCN1*PRLN
      NN=NNO+J
      SN=SINB(NN)
      CN=COSB(NN)
      SN2=SIN2B(NN)
      CN2=COS2B(NN)
      UF=U(K)
      UGF=UG(K)
      UBF=UB(K)
      VF=V(K)
      VGF=VG(K)
      VBF=VB(K)
      WF=W(K)
      WGF=WG(K)
      WBF=WB(K)
      WGGF = WGG(K)
      WBBF = WBB(K)
      WGBF = WGB(K)
      DWGF=DWG(K)
      DWBF=DWB(K)
      IF (NU.EQ.0) PPP=P(K)
      PU=SM*SN2
      PUG=CC5(IR)*CM*SN2
      PUB=CC2(IS)*SM*CN2
      PV=SM2*SN
      PVG=CC1(IR)*CM2*SN
      PVB=CC6(IS)*SM2*CN
      PW = T1*FP5(NN)
      PWG = T2*FP5(NN)
      PWB = T1*FP6(NN)
      PWGG = T3*FP5(NN)
      PWBB = T1*FP7(NN)
      PWGB = T2*FP6(NN)
      PEXXU=XL1*PUG*(1.0+XL1*UGF)
      PEXXV=XL7*VGF*PVG
      PEXXW=XL7*PWG*(WGF+DWGF)
      PETTU=XJ2*UBF*PUB
      PETTV = XJ*PVB*(1.0 + XJ*VBF)
      PETTW = XJ2*PWB*(WBF + DWBF)
      PEXTU=XJ*(PUB*(1.0+XL1*UGF)+XL1*UBF*PUG)
      PEXTV = XL1*(PVG*(1.0 + XJ*VBF) + XJ*VGF*PVB)
      PEXTW = XJ3*(PWB*(WGF+DWGF) + PWG*(WBF+DWBF))
      PKXXW=XL7*PWGG
      PKTTW=XJ2*PWBB
      PKXTW=XJ5*PWGB
      AC = XJ*VBF + XL1*UGF
      PKXXU = XL1*XL7*WGGF*PUG
```

```
      PKXXV = XJ*XL7*WGGF*PVB
      PKXXW = PKXXW + XL7*PWGG*AC
      PKTTU = XJ2*XL1*WBBF*PUG
      PKTTV = PVB*XJ*XJ2*WBBF
      PKTTW = PKTTW + PWBB*XJ2*AC
      PKXTU = XJ4*XL7*WGBF*PUG
      PKXTV = XL3*XJ2*WGBF*PVB
      PKXTW = PKXTW + XJ5*PWGB*AC
      IF(IMASTR.EQ.0) GO TO 1150
      PEXXUS=PEXXU
      PEXXWS=PEXXW
      PKXXUS=PKXXU
      PKXXWS=PKXXW
 1150 S1=0.0
      S2=0.0
      IF (NPLT.EQ.0) GO TO 1200
      PETTV=PETTV+PV*(VF+XJ*WBF) - XJ*WF*PVB
      PETTW=PETTW - PW*(1.0+XJ*VBF-WF) + XJ*VF*PWB
      PEXTV=PEXTV + XL1*(WGF*PV-WF*PVG)
      PEXTW=PEXTW + XL1*(VF*PWG-VGF*PW)
      PKTTU = XL1*PUG + PKTTU
      PKTTV=XJ4*PVB + PKTTV
      PKTTW=PKTTW - PW
      PKXTV=XL1*PVG + PKXTV
      PKXXW = PKXXW - XL7*(PWGG*WF + PW*WGGF)
      IF (IMASTR.NE.0) PKXXWS = PKXXW
      PKTTV = PKTTV + XJ*PVB*(4.*XJ*VBF - 3.*WF) +
     1  PV*(3.*XJ*WBF + 2.*VF)
      PKTTW = PKTTW + XJ2*PWBB*(-WF + XL1*UGF) + PW*(2.*WF -
     1  3.*XJ*VBF - XJ2*WBBF) + PWB*XJ*(4.*XJ*WBF + 3.*VF)
      PKXTV = PKXTV + XL3*PV*WGF
      PKXTW = PKXTW - XJ5*(PWGB*WF + PW*WGBF - PWB*WGF) +
     1  PWG*XL3*(XJ*WBF + VF)
      S1 = DWO(K) + WF
      S2 = VF
 1200 PU = XLP2*PPP*PU*(WGF + DWGF)
      PV = XLP1*PPP*PV*(XJ*(WBF + DWBF) + S2)
      PW = XLP1*PPP*PW*(S1 - XL1*UGF - XJ*VBF - 1.0)
      IF (NOERV.EQ.1) GO TO 1280
      JI = LBAR*(K-1)
      KSUM = KSUMA(K)
      JISTR = LBARST*(KSTR-1)
      KSUMST = KSUMAS(KSTR)
      IF (KSUM.LT.LBAR) GO TO 1300
 1280 G1 = S1A(K)
      G2 = S2A(K)
      G3 = S3A(K)
      G4 = S4A(K)
      G5 = S5A(K)
      G6 = S6A(K)
      F1 = PEXXU*G1 + PETTU*G2 + PEXTU*G3
```

```
      F2 = PKXXU*G4 + PKTTU*G5 + PKXTU*G6
      F3 = PEXXV*G1 + PETTV*G2 + PEXTV*G3
      F4 = PKXXV*G4 + PKTTV*G5 + PKXTV*G6
      F5 = PEXXW*G1 + PETTW*G2 + PEXTW*G3
      F6 = PKXXW*G4 + PKTTW*G5 + PKXTW*G6
      FU = CN10*F1 + CN11*F2
      FV = CN10*F3 + CN11*F4
      FW = CN10*F5 + CN11*F6
      GO TO 1410
C
 1300 TOTUM=0.0
      TOTVM=0.0
      TOTWM = 0.0
      TOTUB = 0.0
      TOTVB = 0.0
      TOTWB = 0.0
      DO 1400 KK=1,LBAR
      L = JI + KK
      S1 = HGD(KK)
      S2 = GX(KK)*S1
      G1 = SXX(L)
      G2 = STT(L)
      G3 = SXT(L)
      TOTUM = TOTUM + S1*(PEXXU*G1 + PETTU*G2 + PEXTU*G3)
      TOTUB = TOTUB + S2*(PKXXU*G1 + PKTTU*G2 + PKXTU*G3)
      TOTVM = TOTVM + S1*(PEXXV*G1 + PETTV*G2 + PEXTV*G3)
      TOTVB = TOTVB + S2*(PKXXV*G1 + PKTTV*G2 + PKXTV*G3)
      TOTWM = TOTWM + S1*(PEXXW*G1 + PETTW*G2 + PEXTW*G3)
      TOTWB = TOTWB + S2*(PKXXW*G1 + PKTTW*G2 + PKXTW*G3)
 1400 CONTINUE
      FU = CN8*TOTUM + CN9*TOTUB
      FV = CN8*TOTVM + CN9*TOTVB
      FW = CN8*TOTWM + CN9*TOTWB
C
 1410 IF (IMASTR.EQ.0) GO TO 1500
      IF (NDERV.EQ.1) GO TO 1420
      IF (KSUMST.LT.LBARST) GO TO 1450
 1420 G7 = S7A(KSTR)
      G8 = S8A(KSTR)
      F7 = PEXXUS * G7
      F8 = PKXXUS * G8
      F9 = PEXXWS * G7
      F0 = PKXXWS * G8
      FUSTR = CN10*F7 + CN11*F8
      FWSTR = CN10*F9 + CN11*F0
      GO TO 1500
C
 1450 TOTUMS = 0.0
      TOTWMS = 0.0
      TOTUBS = 0.0
      TOTWBS = 0.0
```

```
      DO 1470  KKK=1,LBARST
      LSTR = JISTR + KKK
      S3 = HGOSTR(KKK)
      S4 = GXSTR(KKK)*S3
      G4 = SXXSTR(LSTR)
      TOTUMS = TOTUMS + S3*PFXXUS*G4
      TOTUBS = TOTUBS + S4*PKXXUS*G4
      TOTWMS = TOTWMS + S3*PFXXWS*G4
 1470 TOTWBS = TOTWBS + S4*PKXXWS*G4
      FUSTR = CN8*TOTUMS + CN9*TOTUBS
      FWSTR = CN8*TOTWMS + CN9*TOTWBS
C
 1500 SU = SU + (FU + PU)*PRLN
      SV = SV + (FV + PV)*PRLN
      SW = SW + (FW + PW)*PRLN
      IF (IMASTR.EQ.0) GO TO 1600
      SUSTR = SUSTR + FUSTR*PRLNST
      SWSTR = SWSTR + FWSTR*PRLNST
 1600 CONTINUE
      SURS = SURS + PRLM*SU
      SVRS = SVRS + PRLM*SV
      SWRS = SWRS + PRLM*SW
      IF (IMASTR.EQ.0) GO TO 1700
      SURSST = SURSST + PRLM*SUSTR
      SWRSST = SWRSST + PRLM*SWSTR
 1700 CONTINUE
      IF (ABS(SWRS+SWRSST).GT.1.0E30) GO TO 2150
      AAU(IZ,IZ) = 1.0 + AAU(IZ,IZ)
      IZW = MGMB2 + IZ
      AAW(IZ,IZ) = 1.0 + AAW(IZ,IZ)
      BBU(IZ) = -(SURS + SURSST)*CK(1)*CK(2)
      YY(MGMB+IZ) = -SVRS*CK(3)*CK(4)
      BBW(IZ) = -(SWRS + SWRSST)*CK(5)*CK(6)
      IF (NSTR.EQ.0) GO TO 1950
      ISUB = (IR-1)*MB
      DO 1900  ISTR=1,NSTR
      ISUB1 = LOCSTR(ISTR) + ISUB
      STRCON = STRCN2*FP5(ISUB1)
      DO 1900  IQ=1,MB
      ISUB2 = IQ + ISUB
      STRADD = STRCON*FP5(ISUB2)
      AAU(IZ,IQ) = AAU(IZ,IQ) + STRADD
 1900 AAW(IZ,IQ) = AAW(IZ,IQ) + STRADD
      GO TO 2000
 1950 YY(IZ) = BBU(IZ)
      YY(IZW) = BBW(IZ)
 2000 CONTINUE
      IF (NSTR.EQ.0) GO TO 2200
      MAXDIM = IZW - MGMB2
      CALL SOLVE(AAU,MAXDIM,49,0,IPU,0.0,BBU)
      CALL SOLVE(AAW,MAXDIM,49,0,IPW,0.0,BBW)
```

```
 2050 DO 2100  I=1,MAXDIM
      YY(I) = BBU(I)
 2100 YY(I+MGMP2) = BBW(I)
      GO TO 2200
C
 2150 KERR = 1
      WRITE (6,2151)
 2151 FORMAT (31H0SOLUTION DIVERGING IN DEPROSP )
C
 2200 RETURN
C
      END
```

```
      SUBROUTINE DSET1
C
      COMMON/CBLK1/  A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1   MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2   NBNB,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTP,NSYMB,NSYMG,PI
      COMMON/CBLK2/  BETR(23),CC1(13),CC2(13),CC5(13),CC6(13),
     1   CK(6),COSB(299),COSG(299),COS2B(299),COS2G(299),DPRT,DPRT1,
     2   FP1(299),FP2(299),FP3(299),FP4(13,2),FP5(299),FP6(299),
     3   FP7(299),FP8(13,2),
     3   GAM(23),KC,PIMA(23),PINA(23),SINB(299),SING(299),
     4   SIN2B(299),SIN2G(299),XJ,XJ2,XJ3,XJ4,XJ5,XL,XLP,XLP1,XLP2,
     5   XLP3,XL1,XL2,XL3,XL4,XL5,XL7,STRCN1,STRCN2
      COMMON/CBLK3/  GX(6),GXSTR(14),HGO(6),HGOSTR(14)
      COMMON/CBLK4/  NY2,VXO(147),XX(147),YY(147),
     1   AAU(49,49),AAW(49,49),BBU(49),BBW(49),IPJ(49),IPW(49)
      COMMON/CBLK5/  EM(8),EPP(147),FG(13,13),HM(20),MOUT(169),
     1   NOUT(169),RHOM(8),U1(13,13),V1(13,13),W1(13,13)
      COMMON/CBLK7/  BSTR,CN1,CN12,CN13,CN2,CN2STR,CN3,CN4,CN5,CN6,CN7,
     1   EL,EP,EPO,EPP,EPPSTR,H,HSTR,IFIRST,JFIRST,JSTRET,LC,LCMAX,
     2   LCMAXS,LCSTR,NELP,SIGO,SIGO2,TNU,TNUSQ
      COMMON/CBLK8/  NU,P(361),RA(23,23)
      COMMON/CBLK9/  BTL(8),BXL(8),BXLST(8),CCRIT(8),CINST(3),ET(8),
     1   FX(8),GXT(8),NLZ(16),NREG,NTECO,NZP,SAC(8),SAT(8),SMAX,
     2   TCRIT(8),THNU(8),TMAX,XXNU(8),ZC(40),ZCSTR(2)
      COMMON/CBLK10/ DWB(361),DWG(361),DWO(361),        U(361),
     1   UB(361),UG(361),V(361),VB(361),VG(361),W(361),WB(361),
     2   WBB(361),WG(361),WGB(361),WGG(361)
      COMMON/CBLK11/ CM11,CM11ST,CM12,CM22,CM33,DM11,DM11ST,DM12,DM22,
     1   DM33,FM11,FM12,FM22,FM33
      COMMON/CBLK13/ DC,EC,EPSIF,GC,HBAR,NL,NNOUT,RHO,THETAO
      COMMON /CBLK14/ NBUSE(23,23),NRC,C1,C2,C3,C4,C5,C6,C7,
     1  DELX,DELT,    WGGG(44),WBBB(44),WGGB(44),WGBB(44),
     2  VRX(44),VRT(44),RR(4),ENX(44),ENT(44),NKP,KPG(46),KPB(46)
      COMMON/CNOVA/  CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1   KDAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NDBUG,NMASS,NTRIAL,
     2  PB(40),PDAM,PPP,PRINT,REF,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3   ZZ1(3)
      COMMON          CN10,CN11,CN8,CN9,EPBO(1805),EPBOST(1380),ETT,EXT,
     1   EXX,EXXSTR,INZ(2),INZSTR(2),KSUMA(361),KSUMAS(231),KY(1805),
     2   KYSTR(1380),NUSE(23,23),STT(1805),SXT(1805),SXX(1805),
     3   SXXSTR(1380),S1A(361),S2A(361),S3A(361),S4A(361),S5A(361),
     4   S6A(361),S7A(230),S8A(230),UU(13,13),VV(13,13),WW(13,13),
     5   XB(23),XG(23),XKTT,XKXT,XKXX,XKXXST,X1A(361),X2A(361),X3A(361),
     6   X4A(361),X5A(361),X6A(361),X7A(230),X8A(230),ZA(2),ZASTR(2),
     7   ZB(2),ZBSTR(2),ZF(6),ZFSTR(14),ZG(6),ZGSTR(14),ZH(6),ZHSTR(14)
C
C  INPUT DATA
C
      READ (5,7000) MG,MB,MBAR,NBAR,LBAR
      READ (5,7000) (MGM(I),I=1,MG)
      READ (5,7000) (NBN(I),I=1,MB)
```

AD-A053 954 FLORIDA UNIV EGLIN AFB GRADUATE ENGINEERING CENTER F/G 20/11
STUDIES ON THE FAILURE OF STIFFENED CYLINDRICAL SHELLS SUBJECTE--ETC(U)
DEC 77 C A ROSS, R L SIERAKOWSKI AFOSR-77-3237
UNCLASSIFIED AFOSR-TR-78-0697 NL

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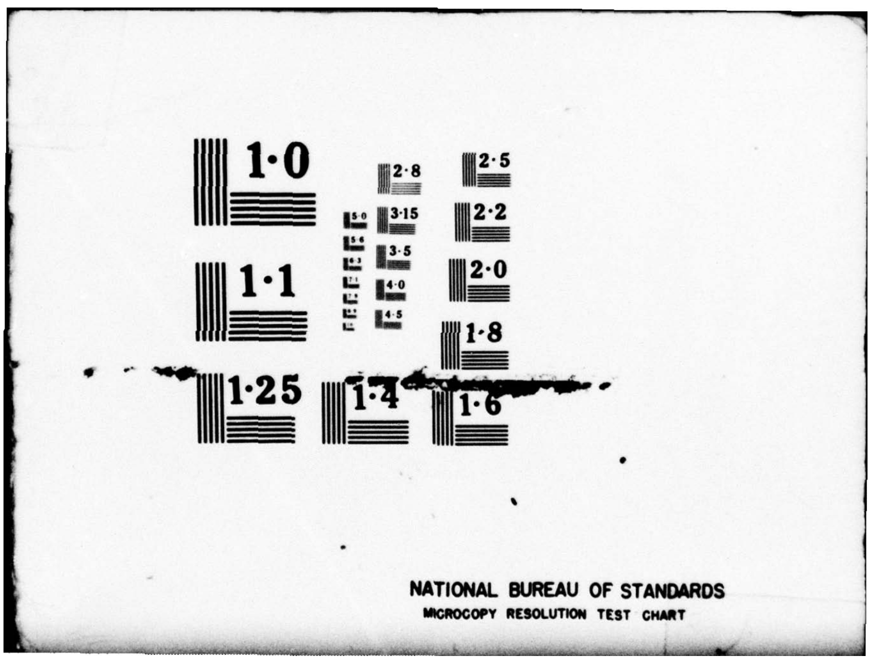
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4·0
4·5
5·0
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

```
      READ (5,7000) NSYMG,NSYMB
      READ (5,7000) MBSTR, LBAPST
      BSTR = 0.0
      HSTR = 0.0
      NSTR = MBSTR
      IF (NSTR.EQ.0) GO TO 40
      IF (NSYMB.EQ.0) NSTR = MBSTR/2 + MOD(MBSTR,2)
      READ (5,7100) BSTR,HSTR
      READ (5,7000) (LOCSTR(I),I=1,NSTR)
   40 READ (5,7000) NPLT,NBND,NDERV
      READ (5,7000) NNOUT
      IF (NNOUT.EQ.0) GO TO 70
      DO 50 I=1,NNOUT
   50 READ (5,7000) MOUT(I),NOUT(I)
   70 READ (5,7000) NKP
      IF (NKP.EQ.0) GO TO 90
      DO 80 I=1,NKP
   80 READ (5,7000) KPG(I),KPB(I)
   90 IF (KDAM.EQ.1.AND.KTYPE.EQ.1) NDERV=2
      IF (KDAM.EQ.1.AND.KTYPE.EQ.3) NDERV = 2
      IF (NDERV.EQ.1) LBAR = 1
      READ (5,7000) NL
      IF (KTYPE.LT.5) NL = 3
      IF (KTYPE.LT.3) NL = 1
      READ (5,7100) XLP,THETA0,A
      IF (NPLT.EQ.0) A=1.0
      IF (NDERV.EQ.1) GO TO 150
      DO 100 I=1,NL
  100 READ (5,7100) HM(I),RHOM(I),EM(I)
      READ (5,7100) TNU,SIGO,EP,EPSIF
      GO TO 190
  150 DO 160 I=1,NL
      READ (5,7100) HM(I),RHOM(I)
      READ (5,7100) EX(I),ET(I),XXNU(I),THNU(I),GXT(I)
  160 READ (5,7100) SAT(I),SAC(I)
      IF (KTYPE.NE.3.AND.KTYPE.NE.4) GO TO 190
      IF (KDAM.NE.0) GO TO 190
      READ (5,7100) EC,GC,DC
  190 READ (5,7100) ((FG(I,J),I=1,MB),J=1,MG)
      READ (5,7100) DELTIM,TSTOP,PRINT
      IF (INOUT.EQ.0) GO TO 2100
C  PRINT OUT THE INPUT
      WRITE(6,7170)
      WRITE (6,7200) MG,MB,MBAR,NBAR,LBAR
      WRITE (6,7210) (MGM(I),I=1,MG)
      WRITE (6,7220) (NBN(I),I=1,MB)
      WRITE (6,7500) MBSTR
      IF (NSTR.GT.0) WRITE (6,7510) BSTR,HSTR,LBAPST,
     1      (LOCSTR(I),I=1,NSTR)
      WRITE (6,7225) NSYMG,NSYMB,NPLT,NBND,NDERV
      WRITE (6,7150) NNOUT
```

```
      IF (NNOUT.GT.0) WRITE(6,7180) (MOUT(I),NOUT(I),I=1,NNOUT)
      WRITE (6,7185) NKP
      IF (NKP.GT.0) WRITE (6,7180) (KPG(I),KPB(I),I=1,NKP)
      WRITE (6,11600) NL,YLP
      IF (NPLT.EQ.0) WRITE(6,7230) THETA0
      IF (NPLT.EQ.1) WRITE(6,7260) THETA0,A
      IF (NDERV.EQ.2) GO TO 1180
      DO 1160 I=1,NL
 1160 WRITE (6,11700) I,HM(I),PHOM(I),EX(I),ET(I),XXNU(I),THNU(I),
     1  GXT(I),SAT(I),SAC(I)
      IF (KTYPE.NE.3.AND.KTYPE.NE.4) GO TO 1190
      IF (KDAM.NE.0) GO TO 1190
      WRITE (6,11900) FC,GC,DC
      GO TO 1190
 1180 WRITE (6,7280) (HM(I),PHOM(I),EM(I),I=1,NL)
      WRITE (6,7300) TNU,SIGO,EP,EPSIF
 1190 WRITE (6,7400) ((FG(I,J),I=1,MB),J=1,MG)
      WRITE(6,8200) DELTIM,TSTOP,PRINT
C
 2100 I=0
      MGMB=0
      DO 2150 M=1,MG
      MM = MGM(M)
      DO 2150 N=1,MB
      NN = NBN(N)
      MUSE(N,M)=1
      IF (I.EQ.NNOUT) GO TO 2130
      DO 2110 J=1,NNOUT
      IF (MM.EQ.MOUT(J).AND.NN.EQ.NOUT(J)) GO TO 2120
 2110 CONTINUE
      GO TO 2130
 2120 MUSE(N,M)=0
      I=I+1
      GO TO 2150
 2130 MGMB=MGMB+1
 2150 CONTINUE
      MGMB2=2*MGMB
      DO 2200 M=1,MG
      MM = MGM(M)
      CC1(M) = MM
 2200 CC5(M) = MM + 1
      XJ=180.0/THETA0
      IF (NPLT.EQ.0) XJ=PI/THETA0
      DO 2300 N=1,MB
      NN = NBN(N)
      CC2(N) = NN
 2300 CC6(N) = NN + 1
      RETURN
C
 7000 FORMAT(6I12)
 7100 FORMAT(6F12.1)
```

```
 7150 FORMAT (9HONNOUT = I3)
 7170 FORMAT (25H1INPUT DATA FOR DEPROSP )
 7180 FORMAT (2I4)
 7185 FORMAT (7HONKP = I3)
 7200 FORMAT(                    10HOMG     = I2/10H MB      = I
     12/10H MBAR   = I2/10H NBAR    = I2/10H LBAR    = I2)
 7210 FORMAT (10HOMGM     = (10I5))
 7220 FORMAT (10HONBN     = (10I5))
 7225 FORMAT (10HONSYMG   = I2/10H NSYMB = I2/10HONPLT   = I2/
     3 10H NBND    = I2/           10H NDERV  = I2)
 7230 FORMAT(17H THETA0, IN      = E16.8)
 7260 FORMAT(17H THETA0, DEG     = E16.8/17H A, IN          = E16.8)
 7280 FORMAT (12H0      HM, IN,4X,21HRHOM, LB-SEC**2/IN**4,4X,
     1   7HEM, PSI/(3E17.8))
 7300 FORMAT(17H0TNU             = E16.8/17H SIGO, PSI       = E16.8/17H EP,
     1 PSI           = E16.8/17H EPSIF, IN/IN  = E16.8)
 7400 FORMAT(5H0FG = /(5E14.6))
 7500 FORMAT(10H0MBSTR   = I2)
 7510 FORMAT(17H BSTR, IN        = E16.8/17H HSTR, IN        = E16.8/
     1   10H LBARST = I5/10H LOCSTR = 6I5)
 8200 FORMAT(15H0DELTIM, SEC = E16.8/15H TSTOP, SEC   = E16.8/15H PRINT
     1        = E16.8)
11600 FORMAT (10H0NL       = I2/17H0XLP, IN        = E16.8)
11700 FORMAT (6H0LAYERI3/27H   HM, IN                  = E16.8/
     1   27H   RHOM, LB-SEC**2/IN**4 = E16.8/
     2   27H   EX, PSI               = E16.8/
     3   27H   ET, PSI               = E16.8/
     4   27H   XXNU                  = E16.8/
     5   27H   THNU                  = E16.8/
     6   27H   GXT, PSI              = E16.8/
     7   27H   SAT, PSI              = E16.8/
     8   27H   SAC, PSI              = E16.8)
11900 FORMAT (11H0EC, PSI = E16.8/11H GC, PSI = E16.8/
     1   11H DC, IN  = E16.8)
      END
```

```
      SUBROUTINE DSET2
C
      COMMON/CBLK1/   A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1   MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2   NBND,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK2/   BETR(23),CO1(13),CO2(13),CO5(13),CO6(13),
     1   CK(6),COSB(299),COSG(299),COS2B(299),COS2G(299),DPRT,DPRT1,
     2   FP1(299),FP2(299),FP3(299),FP4(13,2),FP5(299),FP6(299),
     3   FP7(299),FP8(13,2),
     3   GAM(23),KC,PIMA(23),PINA(23),SINB(299),SING(299),
     4   SIN2B(299),SIN2G(299),XJ,XJ2,XJ3,XJ4,XJ5,XL,XLP,XLP1,XLP2,
     5   XLP3,XL1,XL2,XL3,XL4,XL5,XL7,STRCN1,STRCN2
      COMMON/CBLK3/   GX(6),GXSTR(14),HGO(6),HGOSTR(14)
      COMMON/CBLK4/   NY2,VXO(147),XY(147),YY(147),
     1   AAU(49,49),AAW(49,49),BBU(49),BBW(49),IPJ(49),IPW(49)
      COMMON/CBLK5/   EM(8),EPR(147),FG(13,13),HM(20),MOUT(169),
     1   NOUT(169),PHOM(8),U1(13,13),V1(13,13),W1(13,13)
      COMMON/CBLK7/   BSTR,CN1,CN12,CN13,CN2,CN2STR,CN3,CN4,CN5,CN6,CN7,
     1   EL,EP,EPO,EPP,EPPSTR,H,HSTR,IFIRST,JFIRST,JSTRFT,LC,LCMAX,
     2   LCMAXS,LCSTR,NELP,SIGO,SIGO2,TNU,TNUSQ
      COMMON/CBLK8/   NU,P(361),PA(23,23)
      COMMON/CBLK9/   BTL(8),BXL(8),BXLST(8),CCRIT(8),CINST(3),ET(8),
     1   EX(8),GXT(8),NLZ(16),NREG,NTECO,NZP,SAC(8),SAT(8),SMAX,
     2   TCRIT(8),THNU(8),TMAX,XXNU(8),ZC(40),ZCSTR(2)
      COMMON/CBLK10/  DWB(361),DWG(361),DWO(361),           U(361),
     1   UB(361),UG(361),V(361),VB(361),VG(361),W(361),WB(361),
     2   WBB(361),WG(361),WGB(361),WGG(361)
      COMMON/CBLK11/  CM11,CM11ST,CM12,CM22,CM33,DM11,DM11ST,DM12,DM22,
     1   DM33,FM11,FM12,FM22,FM33
      COMMON/CBLK13/  DC,EC,EPSIF,GC,HBAR,NL,NNOUT,RHO,THETAO
      COMMON/CNOVA/   CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1   KDAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NDBUG,NMASS,NTRIAL,
     2  PB(40),PDAM,PPP,PRINT,PER,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3   ZZ1(9)
      COMMON          CN10,CN11,CN8,CN9,EPBO(1805),EPBOST(1380),ETT,EXT,
     1   EXX,EXXSTR,INZ(2),INZSTR(2),KSUMA(361),KSUMAS(230),KY(1805),
     2   KYSTR(1380),NUSE(23,23),STT(1805),SXT(1805),SXX(1805),
     3   SXXSTR(1380),S1A(361),S2A(361),S3A(361),S4A(361),S5A(361),
     4   S6A(361),S7A(230),S8A(230),UU(13,13),VV(13,13),WW(13,13),
     5   X3(23),XG(23),XKTT,XKXT,XKXX,XKXXST,X1A(361),X2A(361),X3A(361),
     6   X4A(361),X5A(361),X6A(361),X7A(230),X8A(230),ZA(2),ZASTR(2),
     7   ZB(2),ZBSTR(2),ZF(6),ZFSTR(14),ZG(6),ZGSTR(14),ZH(6),ZHSTR(14)
C
      IF (NDERV.EQ.1) GO TO 2710
      CALL LEGEND
      HSTR2 = HSTR * 0.5
      ZBSTR(1) = -HSTR2
      ZBSTR(2) = HSTR2
      IF (LBAR.EQ.0) GO TO 3000
      IF (KTYPE.NE.3) GO TO 2500
C     SET UP EQUIVALENT LAYER FOR HONEYCOMB METAL, NDERV = 2.
```

```
      NELP = 2
      H2=HM(3)*0.5
      HD1=HM(3)-HM(2)
      HD2=HM(1)
      ZB(1)=-H2+0.5*HD2
      ZB(2) = H2 - .5*HD1
      SUMRH=0.0
      H0=0.0
      DO 2400 I=1,3
      H1=HM(I)
      SUMRH=SUMRH+RHOM(I)*(H1-H0)
 2400 H0=H1
      NL=1
      EQC=HM(3)-HM(2)+HM(1)
      EQH=(HM(3)+HM(2)-HM(1))*SQRT(3.0*HM(1)*(HM(3)-HM(2)))/EQC
      RHO=SUMRH/EQH
      H=EQH
      HM(1)=H
      EL=EM(1)*EQC/EQH
      EP=EP*EQC/EQH
      SIGO=SIGO*EQC/EQH
      EM(1)=EL
      IF (KDAM.EQ.2) GO TO 2705
      TCRIT(1)=EPSIF
      GO TO 2705
C     SINGLE LAYER, NDERV = 2.
 2500 H = HM(1)
      EL=EM(1)
      RHO=RHOM(1)
      H2=0.5*H
      ZB(1)=-H2
      ZB(2) = H2
      NELP = 2
      IF (KDAM-1) 2600,2700,2705
C  NO DAMAGE
 2600 TCRIT(1)=SIGO
      CCRIT(1)=SIGO
      NELP = 1
      GO TO 2705
 2700 TCRIT(1)=EPSIF
      IF (KTYPE.EQ.1) GO TO 2705
      TCRIT(1) = SIGO
      NELP = 1
 2705 DT = DELTIM
      F3=RHO*(1.0 - TNU**2)/EL
      F1 = H**2/(12.0*F3)
      F2= SIGO/RHO
      CALL DTSTEP (F1,F2,F3,F3,F1)
      IF (DT.GT.0.0) DELTIM = DT
      GO TO 2750
C
```

```
C       NDERV = 1.
C       COMPUTE HBAR.
 2710 A1 = 0.
      A2 = 0.
      A3 = 0.
      A4 = 0.
      A5 = 0.
      A6 = 0.
      A7 = 0.
      A8 = 0.
      H0 = 0.
      DO 2715 I=1,NL
      H1 = HM(I)
      B22 = 1./(1. - XXNU(I)*THNU(I))
      B11 = EX(I)*B22
      B22 = ET(I)*B22
      B12 = XXNU(I)*B22
      B33 = GXT(I)
      BXL(I) = B11
      BTL(I) = B22
      BXLST(I) = EX(I)
      D1 = H1 - H0
      D2 = H1**2 - H0**2
      A1 = A1 + B11*D2
      A2 = A2 + B11*D1
      A3 = A3 + B22*D2
      A4 = A4 + B22*D1
      A5 = A5 + B33*D2
      A6 = A6 + B33*D1
      A7 = A7 + B12*D2
      A8 = A8 + B12*D1
 2715 H0 = H1
      HB11 = .5*A1/A2
      HB22 = .5*A3/A4
      HB33 = .5*A5/A6
      HB12 = .5*A7/A8
      HBAR = .25*(HB11 + HB22 + HB33 + HB12)
C
      RHOBR = 0.
      CM11 = 0.
      CM12 = 0.
      CM22 = 0.
      CM33 = 0.
      FM11 = 0.
      FM12 = 0.
      FM22 = 0.
      FM33 = 0.
      DM11 = 0.
      DM12 = 0.
      DM22 = 0.
      DM33 = 0.
```

```
      CM11ST = 0.
      DM11ST = 0.
      F=0.0
      H0 = 0.
      DO 2720 I=1,NL
      H1 = HM(I)
      H1ST = (HSTR/NL)*I
      BTT = BTL(I)
      XNUB = XXNU(I)*BTT
      BXX = BXL(I)
      BXXST = BXLST(I)
      GXTL = GXT(I)
      RHOL = RHOM(I)
      H11 = H1 - H0
      H11ST = H1ST
      F= F + SAT(I)*H11
      CM11 = CM11 + BXX*H11
      CM12 = CM12 + XNUB*H11
      CM22 = CM22 + BTT*H11
      CM33 = CM33 + GXTL*H11
      CM11ST = CM11ST + BXXST*H11ST
      RHOBR = RHOBR + RHOL*H11
      H12 = H1**2 - H0**2
      H12D = H12 - 2.*HBAR*H11
      FM11 = FM11 + BXX*H12D
      FM12 = FM12 + XNUB*H12D
      FM22 = FM22 + BTT*H12D
      FM33 = FM33 + GXTL*H12D
      H13 = H1**3 - H0**3
      H13D = H13 - 3.*HBAR*H12 + 3.*HBAR**2*H11
      DM11 = DM11 + BXX*H13D
      DM12 = DM12 + XNUB*H13D
      DM22 = DM22 + BTT*H13D
      DM33 = DM33 + GXTL*H13D
      DM11ST = DM11ST + (BXXST*H11ST**3)/4.0
2720  H0 = H1
      OH3 = 1./HM(NL)
      OA = 1./A
      O2A2 = 1./(2.*A**2)
      O3A3 = 1./(3.*A**3)
      CM11 = CM11*OA
      CM12 = CM12*OA
      CM22 = CM22*OA
      CM33 = CM33*OA
      CM11ST = CM11ST*OA
      FM11 = FM11*O2A2
      FM12 = FM12*O2A2
      FM22 = FM22*O2A2
      FM33 = FM33*O2A2
      DM11 = DM11*O3A3
      DM12 = DM12*O3A3
```

```
      DM22 = DM22*D3A3
      DM33 = DM33*D3A3
      DM11ST = DM11ST*D3A3
      RHOBR = RHOBR*DH3
      RHO = RHOBR
      H = HM(NL)
      F3=RHO/DH3
      F1=DM22*A**3/F3
      F2=F/F3
      F4 = F3/(A*DM11)
      F5 = DM11*A**3/F3
      F3=F3/(A*DM22)
      DT = DELTIM
      CALL DTSTEP (F1,F2,F3,F4,F5)
      IF (DT.GT.0.0) DELTIM = DT
      NELP = 1
      NZP = 2
      ZCSTR(1) = -HSTR*0.5
      ZCSTR(2) = ZCSTR(1) + HSTR
      IF (KTYPE.EQ.5) GO TO 2730
      NLZ(1) = 1
      ZC(1) = -HBAR
      NLZ(2) = 1
      ZC(2) = ZC(1) + H
      IF (KTYPE.LT.3) GO TO 2745
      NLZ(2) = 3
      ZC(1) = ZC(1) + .5*HM(1)
      ZC(2) = ZC(2) - .5*(HM(3) - HM(2))
      GO TO 2745
 2730 HT = -HBAR
      HS = HM(1)
      DO 2740 I=1,NL
      NLZ(2*I - 1) = I
      NLZ(2*I) = I
      ZC(2*I - 1) = HT
      IF (I.GT.1) HS = HM(I) - HM(I-1)
      HT = HT + HS
 2740 ZC(2*I) = HT
      NZP = 2*NL
 2745 IF (KDAM.EQ.2) GO TO 2800
      DO 2747 I=1,NL
      TCRIT(I) = SAT(I)
 2747 DCRIT(I) = SAC(I)
 2750 CONTINUE
 2800 RETURN
 3000 KERR = 1
      RETURN
      END
```

```
      SUBROUTINE OSFT3
C
      COMMON/CBLK1/   A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1    MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2    NBNC,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK2/   BETR(23),CC1(13),CC2(13),CC5(13),CC6(13),
     1    CK(6),COSB(299),COSG(299),COS2B(299),COS2G(299),DPRT,DPRT1,
     2    FP1(299),FP2(299),FP3(299),FP4(13,2),FP5(299),FP6(299),
     3    FP7(299),FP8(13,2),
     3    GAM(23),KC,PIMA(23),PINA(23),SINB(299),SING(299),
     4    SIN2B(299),SIN2G(299),XJ,XJ2,XJ3,XJ4,XJ5,XL,XLP,XLP1,XLP2,
     5    XLP3,XL1,XL2,XL3,XL4,XL5,XL7,STRCN1,STRCN2
      COMMON/CBLK3/   GX(6),GXSTR(14),HGO(6),HGOSTR(14)
      COMMON/CBLK4/   NY2,VXO(147),XX(147),YY(147),
     1    AAU(49,49),AAW(49,49),BBU(49),BBW(49),IPJ(49),IPW(49)
      COMMON/CBLK5/   EM(8),EPR(147),FG(13,13),HM(20),MOUT(169),
     1    NOUT(169),PHOM(8),U1(13,13),V1(13,13),W1(13,13)
      COMMON/CBLK7/   BSTR,CN1,CN12,CN13,CN2,CN2STR,CN3,CN4,CN5,CN6,CN7,
     1    EL,EP,EPO,EPP,EPPSTR,H,HSTR,IFIRST,JFIRST,JSTRET,LC,LCMAX,
     2    LCMAXS,LCSTR,NELP,SIGO,SIGO2,TNU,TNUSQ
      COMMON/CBLK8/   NU,P(361),RA(23,23)
      COMMON/CBLK9/   BTL(8),BXL(8),BXLST(8),CCRIT(8),CINST(3),ET(8),
     1    EX(8),GXT(8),NLZ(16),NREG,NTECO,NZP,SAC(8),SAT(8),SMAX,
     2    TCRIT(8),THNU(8),TMAX,XXNU(8),ZC(40),ZCSTR(2)
      COMMON/CBLK10/  DWB(361),DWG(361),DWO(361),         U(361),
     1    UB(361),UG(361),V(361),VB(361),VG(361),W(361),WB(361),
     2    WBB(361),WG(361),WGB(361),WGG(361)
      COMMON/CBLK11/  CM11,CM11ST,CM12,CM22,CM33,DM11,DM11ST,DM12,DM22,
     1    DM33,FM11,FM12,FM22,FM33
      COMMON/CBLK13/  DC,EC,EPSIF,GC,HBAR,NL,NNOUT,RHO,THETAO
      COMMON /CBLK14/ NBUSE(23,23),NRC,C1,C2,C3,C4,C5,C6,C7,
     1  DELX,DELT,     WGGG(44),WBBB(44),WGGB(44),WGBB(44),
     2  VRX(44),VRT(44),RR(4),ENX(44),ENT(44),NKP,KPG(46),KPB(46)
      COMMON/CNOVA/   CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1    KDAM,KDS,KEPR,KOK,KTYPE,NCALL,NCASE,NCHPT,NDBUG,NMASS,NTRIAL,
     2   PB(49),PDAM,PPP,PRINT,RFR,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3    ZZ1(9)
      COMMON          CN10,CN11,CN8,CN9,EPBO(1805),EPBOST(1380),ETT,EXT,
     1    EXX,EXXSTR,INZ(2),INZSTR(2),KSUMA(361),KSUMAS(230),KY(1805),
     2    KYSTR(1380),NUSE(23,23),STT(1805),SXT(1805),SXX(1805),
     3    SXXSTR(1380),S1A(361),S2A(361),S3A(361),S4A(361),S5A(361),
     4    S6A(361),S7A(230),S8A(230),UU(13,13),VV(13,13),WW(13,13),
     5    XB(23),XG(23),XKTT,XKXT,XKXX,XKXXST,X1A(361),X2A(361),X3A(361),
     6    X4A(361),X5A(361),X6A(361),X7A(230),X8A(230),ZA(2),ZASTR(2),
     7    ZB(2),ZBSTR(2),ZF(6),ZFSTR(14),ZG(6),ZGSTR(14),ZH(6),ZHSTR(14)
C
C   PRINTOUT DESCRIPTION OF DEPROSP DATA
C
 2800 WRITE(6,9300)
      IF (NPLT.EQ.0) WRITE(6,9400)
      IF (NPLT.EQ.1) WRITE(6,9500)
```

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```
      GO TO (2820,2840,2860,2880,2900), KTYPE
 2820 WRITE (6,9600)
      GO TO 2950
 2840 WRITE (6,9700)
      GO TO 2950
 2860 WRITE (6,9800)
      GO TO 2950
 2880 WRITE (6,9820)
      GO TO 2950
 2900 WRITE (6,9840)
 2950 IF (NBND.EQ.1.OR.NBND.EQ.3.OR.NBND.EQ.6) WRITE (6,9900)
      IF (NBND.EQ.2.OR.NBND.EQ.4.OR.NBND.EQ.8) WRITE (6,9920)
      IF (NBND.EQ.5.OR.NBND.EQ.7.OR.NBND.EQ.9) WRITE (6,9940)
      IF (NBND.EQ.1.OR.NBND.EQ.4.OR.NBND.EQ.5) WRITE (6,9960)
      IF (NBND.EQ.2.OR.NBND.EQ.3.OR.NBND.EQ.7) WRITE (6,9980)
      IF (NBND.EQ.6.OR.NBND.EQ.8.OR.NBND.EQ.9) WRITE (6,10000)
      IF (NDERV.EQ.1) WRITE(6,10100)
      IF (NDERV.EQ.2) WRITE(6,10200)
      WRITE(6,10800) MG,MB,MBAR,NBAR,LBAR
      IF (NSTR.NE.0) WRITE(6,10810) MBSTR, LBARST
      WRITE (6,10820)
      DO 2970 M=1,MG
      MM = MGM(M)
      DO 2970 N=1,MB
      NN = NBN(N)
      IF (MUSE(N,M).EQ.0) GO TO 2970
      WRITE (6,10830) MM,NN
 2970 CONTINUE
      WRITE (6,10850) YLP
      IF (NPLT.EQ.0) WRITE(6,10900) THETA0
      IF (NPLT.EQ.1) WRITE(6,11000)THETA0,A
      IF (NDERV.EQ.2) GO TO 3500
      WRITE (6,12050) HBAR,(I,I=1,NL)
      WRITE (6,12100) (HM(I),I=1,NL)
      WRITE (6,12200) (RHOM(I),I=1,NL)
      WRITE (6,12300) (EX(I),I=1,NL)
      WRITE (6,12400) (ET(I),I=1,NL)
      WRITE (6,12500) (XXNU(I),I=1,NL)
      WRITE (6,12600) (THNU(I),I=1,NL)
      WRITE (6,12650) (GXT(I),I=1,NL)
      IF (KTYPE.NE.1.AND.KTYPE.NE.3) GO TO 3300
      WRITE (6,12900) (SAT(I),I=1,NL)
      WRITE (6,13000) (SAC(I),I=1,NL)
      GO TO 3400
 3300 WRITE (6,12700) (SAT(I),I=1,NL)
      WRITE (6,12800) (SAC(I),I=1,NL)
 3400 IF (KTYPE.NE.3.AND.KTYPE.NE.4) GO TO 3600
      IF (KDAM.NE.0) GO TO 3600
      WRITE (6,13100) EC,GC,DC
      GO TO 3600
 3500 WRITE (6,11100) H,RHO,EL,TNU,STGO,EP,EPSIF
```

```
3600 WRITE (6,11200) ((FG(N,M),N=1,MB),M=1,MG)
     WRITE(6,11300) DELTIM,TSTOP,PRINT
     IF (NDERV.EQ.1) GO TO 4020
     DO 4000 K=1,LBAR
     ZH(K)=GX(K)*H*0.5
     ZF(K)=ZH(K)/A
     ZG(K)=GX(K)**2
4000 CONTINUE
     ZA(1) = ZB(1)/A
     ZA(2) = ZB(2)/A
     INZ(1) = 1
     INZ(2) = LBAR
     IF (NSTR.EQ.0) GO TO 4020
     DO 4010  K=1,LBARST
     ZHSTR(K) = GXSTR(K)*HSTR*0.5
     ZFSTR(K) = ZHSTR(K)/A
     ZGSTR(K) = GXSTR(K)**2
4010 CONTINUE
     ZASTR(1) = ZBSTR(1) / A
     ZASTR(2) = ZBSTR(2) / A
     INZSTR(1) = 1
     INZSTR(2) = LBARST
4020 NNSYMG = 0
     NNSYMB = 0
     IF (NBND.EQ.5.OR.NBND.EQ.7.OR.NBND.EQ.9) NNSYMG = 1
     IF (NBND.EQ.6.OR.NBND.GE.8) NNSYMB = 1
     IF (NNSYMG.EQ.1.AND.NSYMG.EQ.0) WRITE (6,13200)
     IF (NNSYMB.EQ.1.AND.NSYMB.EQ.0) WRITE (6,13200)
     NGT = MBAR
     NBT = NBAR
     NG = NGT
     NB = NBT
     IF (NSYMG.EQ.1) NG = (NGT+1)/2
     IF (NSYMB.EQ.1) NB = (NBT+1)/2
     NY2 = 3*MGMB
     PIM = PI/FLOAT(2*(MBAR-1))
     PIN = PI/FLOAT(2*(NBAR-1))
     IF (NSYMG.EQ.1) PIM = 2.*PIM
     IF (NSYMB.EQ.1) PIN = 2.*PIN
     R=A/H
     XL=XLP/(PI*A)
     XL1=1.0/XL
     XL2=XL**2
     XL3=2.0*XL1
     XL4=2.0*XL2
     XL5=XL4*R
     XL7=1.0/XL2
     CN8 = XL**2
     CN9 = CN8/(2.0*R)
     IF (NDERV.EQ.1) GO TO 4040
     C1 = 1.0/(A**2*XL**3)
```

```
      C2 = (XJ/A)**2/XL
      C3 = (XJ/A)**2*XJ
      C4 = XJ/(A*XL)**2
      C5 = -H**2/2.0
      C6 = H**3/8.0
      DELX = PIM*XLP/PI
      DELT = PIN*THETA0/PI
      DELT = A*DELT
      CN10 = 2.0*CN8
      CN11 = CN9/(3.0*R)
      GO TO 4050
 4040 CN10 = 2.*CN8*R
      CN11 = CN10
      C1 = DM11*A/XL**3
      C2 = (DM12 + 4.0*DM33)*A*XJ**2/XL
      C3 = DM22*A*XJ**3
      C4 = (DM12 + 4.0*DM33)*A*XJ/XL**2
      C5 = -4.0*DM33*XJ*A**2/XL
 4050 XJ2 = XJ**2
      XJ3=XJ*XL1
      XJ4=2.0*XJ
      XJ5=2.0*XJ3
      DPRT1=PRINT*DELTIM
      XLP1=XL5
      XLP2=2.0*XL*2
      XLP3=1.0/XLP1
      PPL = 1./(RHO*XLP**2)
C     SIMPSON S RULE.
C     MBAR AND NBAR MUST BE ODD NUMBERS FOR FULL PANEL.
      DO 4100 I=1,MBAR
      F = I-1
      GAM(I) = F*PIM
      XG(I) = GAM(I)*XLP/PI
      PIMA(I) = PPL*4.*PIM/3.
      IF (NSYMG.EQ.1) PIMA(I) = .5*PIMA(I)
      IF ((I+1)/2.EQ.I/2) PIMA(I) = 2.*PIMA(I)
 4100 CONTINUE
      PIMA(1) = PIMA(1)*.5
      PIMA(MBAR) = PIMA(MBAR)*.5
      DO 4200 I=1,NBAR
      F = I-1
      BETR(I) = F*PIN
      XB(I) = BETR(I)*THETA0/PI
      PINA(I) =      4.*PIN/3.
      IF (NSYMB.EQ.1) PINA(I) = .5*PINA(I)
      IF ((I+1)/2.EQ.I/2) PINA(I) = PINA(I)*2.
 4200 CONTINUE
      PINA(1) = .50*PINA(1)
      PINA(NBAR) = PINA(NBAR)*.5
      STRCN1=PSTR*XJ/A
      STRCN2=HSTR*STRCN1/(PI*H)
```

```
      DO 4400 I=1,MBAR
      DO 4400 J=1,NBAR
      NBUSE(J,I) = 0
 4400 NUSE(J,I) = 2
      II = 0
      DO 4430 I=1,NGT
      DO 4430 J=1,NBT
      IF (II.EQ.NKP) GO TO 4430
      DO 4410 K=1,NKP
      IF (I.EQ.KPG(K).AND.J.EQ.KPB(K)) GO TO 4420
 4410 CONTINUE
      GO TO 4430
 4420 NUSE(J,I) = 3
      II = II + 1
 4430 CONTINUE
      N1 = NBAR - NSYMB
      K = 0
      DO 4440 J=2,N1
      K = K + 1
      IF (NUSE(J,1).GT.2) NBUSE(J,1) = -K
      IF (NSYMG.EQ.1.AND.NUSE(J,MBAR).GT.2) NBUSE(J,MBAR) = -K-N1+1
 4440 CONTINUE
      N1 = MBAR - NSYMG
      K = 0
      DO 4450 I=2,N1
      K = K + 1
      IF (NUSE(1,I).GT.2) NBUSE(1,I) = K
      IF (NSYMB.EQ.1.AND.NUSE(NBAR,I).GT.2) NBUSE(NBAR,I) = K+N1-1
 4450 CONTINUE
      NBUSE(1,1) = 101
      IF (NSYMB.EQ.1) NBUSE(NBAR,1) = 102
      IF (NSYMG.EQ.1) NBUSE(1,MBAR) = 103
      IF (NSYMG*NSYMB.EQ.1) NBUSE(NBAR,MBAR) = 104
      NRC = 1 + NSYMB + 2*NSYMG
      II=0
      DO 4500 M=1,MG
      X1 = MGM(M) + 1
      DO 4500 I=1,NGT
      II=II+1
      SING(II)=SIN(X1*GAM(I))
      COSG(II)=COS(X1*GAM(I))
      SIN2G(II)=SIN((X1-1.0)*GAM(I))
      COS2G(II)=COS((X1-1.0)*GAM(I))
 4500 CONTINUE
      II=0
      DO 4500 N=1,MB
      X1 = NBN(N) + 1
      DO 4500 J=1,NBT
      II=II+1
      SINB(II)=SIN(X1*BETB(J))
      COSB(II)=COS(X1*BETB(J))
```

```
      SIN23(II)=SIN((X1-1.0)*BETR(J))
      COS23(II)=COS((X1-1.0)*BETR(J))
 4600 CONTINUE
C
      CALL BOLT
C
 4800 K=0
      OA=1.0/A
      DO 5200 I=1,NGT
      DO 5200 J=1,NBT
      IF (NUSE(J,I).EQ.0) GO TO 5200
      K=K+1
      DWO(K)=0.0
      DWG(K)=0.0
      DWB(K)=0.0
      DO 5100 M=1,MG
      MM=(M-1)*NGT + I
      DO 5100 N=1,MB
      IF (MUSE(N,M).EQ.0) GO TO 5100
      NN=(N-1)*NBT + J
      FGMN=FG(N,M)*OA
      DWO(K) = FGMN*FP1(MM)*FP5(NN) + DWO(K)
      DWG(K) = FGMN*FP2(MM)*FP5(NN) + DWG(K)
      DWB(K) = FGMN*FP1(MM)*FP6(NN) + DWB(K)
 5100 CONTINUE
 5200 CONTINUE
      NGNBT = K
      LMAX = LBAR*NGNBT
      LMAXST = LBARST*NSTR*NBT
      NGNB = NG*NB
      RETURN
C
 9300 FORMAT(1H1,25X,13HD E P R O P  /15HOPANEL ANALYZED)
 9400 FORMAT(7H   FLAT)
 9500 FORMAT(9H   CURVED)
 9600 FORMAT(22H   METAL, SINGLE LAYER)
 9700 FORMAT(24H   PLASTIC, SINGLE LAYER)
 9800 FORMAT(19H   METAL, HONEYCOMB)
 9820 FORMAT (21H   PLASTIC, HONEYCOMB)
 9840 FORMAT (22H   PLASTIC, MULTILAYER)
 9900 FORMAT (37H   CLAMPED - CLAMPED, GAMMA DIRECTION)
 9920 FORMAT (35H   SIMPLE - SIMPLE, GAMMA DIRECTION)
 9940 FORMAT (36H   CLAMPED - SIMPLE, GAMMA DIRECTION)
 9960 FORMAT (36H   CLAMPED - CLAMPED, BETA DIRECTION)
 9980 FORMAT (34H   SIMPLE - SIMPLE, BETA DIRECTION)
10000 FORMAT (35H   CLAMPED - SIMPLE, BETA DIRECTION)
10100 FORMAT(26H0RESPONSE OPTION - ELASTIC)
10200 FORMAT(34H0RESPONSE OPTION - ELASTIC-PLASTIC)
10800 FORMAT(17H0STRUCTURAL MODEL/
     1 47H   NUMBER OF GAMMA MODES  (MG)                    = I3/
     2 47H   NUMBER OF BETA MODES  (MB)                     = I3/
```

```
     3 47H0   NUMBER OF GAMMA INTEGRATION POINTS (MBAR) = I3/
     4 47H    NUMBER OF BETA INTEGRATION POINTS  (NBAR) = I3/
     5 47H    NUMBER OF Z INTEGRATION POINTS     (LBAR) = I3)
10810 FORMAT (1H /
     1 47H    NUMBER OF STRINGERS                      (MBSTR) = I3/
     2 47H    NUMBER OF STRINGER Z INTEGR. PTS.(LBARST) = I3)
10820 FORMAT (24H0MODAL COMBINATIONS USED)
10830 FORMAT (3X,2I4)
10850 FORMAT (35H0  LENGTH OF PANEL, IN (XLP)        = E16.8)
10900 FORMAT(35H   WIDTH OF PANEL, IN (THETA0)    = E16.8)
11000 FORMAT(35H   SUBTENDED ANGLE, DEG (THETA0) = E16.8/
     2 35H    RADIUS, IN (A)                  = E16.8)
11100 FORMAT(35H   THICKNESS, IN                      = E16.8/
     1  35H    DENSITY, LB-SEC**2/IN**4        = E16.8/
     2 35H    ELASTIC MODULUS, PSI             = E16.8/
     3 35H    POISSON'S RATIO                  = E16.8/
     4 35H    YIELD STRESS, PSI                = E16.8/
     5 35H    STRAIN HARDENING SLOPE, PSI    = E16.8/
     6 35H    ULTIMATE STRAIN, IN/IN (EPSIF)= E16.8)
11200 FORMAT(26H0INITIAL IMPERFECTIONS, IN/(5E14.5))
11300 FORMAT(17H0TIME INFORMATION/
     1 42H    INTEGRATION STEP SIZE, SEC (DELTIM)  = E16.8/
     2 42H    STOP TIME, SEC (TSTOP)                = E16.8/
     3 42H    PRINT FREQUENCY (PRINT)               = E16.8)
12050 FORMAT (40H0COORDINATE SURFACE POSITION (H3AR), IN    E16.8/
     1   13H0LAYER NUMBER,22X,4I15/(31X,4I15))
12100 FORMAT (27H    CUMULATIVE THICKNESS, IN,13X,6E15.6)
12200 FORMAT (32H    MASS DENSITY, LB-SEC**2/IN**4,8X,6E15.6)
12300 FORMAT (33H    MODULUS OF ELASTICITY - X, PSI,7X,6E15.6)
12400 FORMAT (40H    MODULUS OF ELASTICITY - THETA, PSI   6E15.6)
12500 FORMAT (22H    POISSON'S RATIO - X,18X,6E15.6)
12600 FORMAT (26H    POISSON'S RATIO - THETA,14X,6E15.6)
12700 FORMAT (31H    TENSILE ULTIMATE STRESS, PSI,9X,6E15.6)
12800 FORMAT (35H    COMPRESSIVE ULTIMATE STRESS, PSI,5X,6E15.6)
12900 FORMAT (28H    TENSILE YIELD STRESS, PSI,12X,6E15.6)
13000 FORMAT (32H    COMPRESSIVE YIELD STRESS, PSI,8X,6E15.6)
12650 FORMAT (21H    SHEAR MODULUS, PSI,19X,6E15.6)
13100 FORMAT (62H0CORE MODULUS OF ELASTICITY PARALLEL TO CORE DEPTH (EC)
     1, PSI = E15.6/
     2  63H SHEAR MODULUS OF CORE (GC), PSI                              =
     3  E14.6/
     4  62H CORE CELL SIZE (DC), IN                                       =
     5  E15.6)
13200 FORMAT (41H0** WARNING **  INCONSISTENCY IN SYMMETRY)
      END
```

```
      SUBROUTINE DTSTEP (F1,F2,F3,F4,F5)
C
C     THIS SUBROUTINE COMPUTES AN APPROXIMATE, CONSERVATIVE
C     TIME STEP FOR DEPROSP.
C     NOTE:  IT IS ASSUMED THAT FOR A FLAT PANEL THETA0 .LT. XL.
C
      COMMON/DBLK1/   A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1   MBAR,MBSTR,MG,MGM(13),MGMB,MGMBR,MUSE(13,13),NB,NBAR,NBN(13),
     2   NBND,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/DBLK2/   BETR(23),CC1(13),CC2(13),CC5(13),CC6(13),
     1   CK(6),COSB(299),COSG(299),COS2B(299),COS2G(299),DPRT,DPRT1,
     2   FP1(299),FP2(299),FP3(299),FP4(13,2),FP5(299),FP6(299),
     3   FP7(299),FP8(13,2),
     3   GAM(23),KC,PIMA(23),PINA(23),SINB(299),SING(299),
     4   SIN2B(299),SIN2G(299),XJ,XJ2,XJ3,XJ4,XJ5,XL,XLP,XLP1,XLP2,
     5   XLP3,XL1,XL2,XL3,XL4,XL5,XL7,STRCN1,STRCN2
      COMMON/DBLK13/ DC,EC,EPSIF,GC,HBAR,NL,NNOUT,RHO,THETA0
      COMMON/CNOVA/   CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1   KDAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NDBUG,NMASS,NTRIAL,
     2  PB(40),PDAM,PPP,PRINT,RER,PTRIAL(5),TIME,TITLE(20),TSTOP,
     3   ZZ1(9)
C
      BN = NBAR
      IF (NSYMB.EQ.0) BN = 2*NBAR - 1
      THETR = PI*THETA0/180.
      BM = MBAR
      IF (NSYMG.EQ.0) BM = 2*MBAR - 1
      CM=0.0
      IF (NBND.EQ.1 .OR. NBND.EQ.3 .OR. NBND.EQ.6) CM=0.30
      IF (NBND.EQ.5 .OR. NBND.EQ.7 .OR. NBND.EQ.9) CM=0.15
      CN=0.0
      IF (NBND.EQ.1 .OR. NBND.EQ.4 .OR. NBND.EQ.5) CN=0.30
      IF (NBND.EQ.6 .OR. NBND.GE.8) CN=0.15
      DT1X = 1.0E6
      DT2X = 1.0E6
      DT3X = 1.0E6
      DT4X = 1.0E6
      DT5X = 1.0E6
      IF (NPLT.EQ.0) DT2X = THETA0*SQRT(F3)/(BN - 1.0)
      IF (NPLT.EQ.1) DT3X = A*THETR*SQRT(F3)/(BN - 1.0)
      IF (NPLT.EQ.1) DT4X = XLP*SQRT(F4)/(BM - 1.0)
C     CHECK ALL MODAL COMBINATIONS.
      DO 200 M=1,MG
      BARM = MGM(M)
      DO 200 N=1,MB
      IF (MUSE(N,M).EQ.0) GO TO 200
      BARN = NBN(N)
      BARMX=BARM + CM
      BARNX = BARN + CN
      IF (NPLT.EQ.1) GO TO 100
C     FLAT PANEL
```

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```
      ELMN = (BARMX*PI/XLP)**2 + (BARNX*PI/THETA0)**2
      DT1 = PI        /SQRT(ELMN*(F2 + ELMN*F1))
      DT1 = DT1 / 25.0
      IF (DT1.LT.DT1X) DT1X = DT1
      GO TO 200
C
C     CURVED PANEL
  100 ELMN = BARMX*PI*A/XLP
      EKMN = BARNX*PI/THETR
      DUM = (ELMN**2 + EKMN**2)**2
      DT1 = PI*A        *SQRT(F3/(0.5*(1.0 + ELMN**2) - 0.5*SQRT((1.0 -
     1 ELMN**2)**2 + 4.0*(0.30*ELMN)**2)))
      DT1 = DT1/35.0
      DT2 = PI*A        /SQRT(F1*DUM/A**2 + ELMN**4/(F3*DUM))
      DT2 = DT2/35.0
      ELMN = SQRT(DUM)/A**2
      DT5 = PI        /SQRT(ELMN*(F2 + ELMN*F5))
      DT5 = DT5/25.0
      IF (DT1.LT.DT1X) DT1X = DT1
      IF (DT2.LT.DT2X) DT2X = DT2
      IF (DT5.LT.DT5X) DT5X = DT5
  200 CONTINUE
      IF (NPLT.EQ.0) DELTIM = AMIN1(DT1X,DT2X)
      IF (NPLT.EQ.1) DELTIM = AMIN1(DT1X,DT2X,DT3X,DT4X,DT5X)
      IF (NDBUG.GT.0) WRITE (6,1000) DT1X,DT2X,DT3X,DT4X,DT5X
      RETURN
C
 1000 FORMAT (31H0DERROSP TIME STEP CALCULATIONS/5E15.6)
      END
```

```
      SUBROUTINE HIM (K,NEQ,DELTIM,TIME,VXO,X4,AX4)
C
C     SPECIAL INTEGRATION METHOD FOR 2ND ORDER DIFFERENTIAL EQUATIONS
C       WHICH HAVE NO DAMPING.  CENTRAL DIFFERENCE SCHEME.
C
      COMMON/CHIM/ X3(147),DTSQ
      DIMENSION X4(1),AX4(1),VXO(1)
C
      IF (K.GT.1) GO TO 200
      DTSQ = DELTIM**2
      K = 2
      DO 100 I=1,NEQ
  100 X3(I) = X4(I) - VXO(I)*DELTIM + 0.5*DTSQ*AX4(I)
C
  200 DO 300 I=1,NEQ
      X = 2.*X4(I) - X3(I) + DTSQ*AX4(I)
      X3(I) = X4(I)
  300 X4(I) = X
      TIME = TIME + DELTIM
      RETURN
      END
```

```
      SUBROUTINE LEGEND
C
C     THIS ROUTINE CONTAINS THE LEGENDRE ZEROES AND
C     WEIGHTING FACTORS FOR LBAR AND LBARST .LE. 14.
C
      COMMON/CBLK1/   A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1   MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2   NBNB,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK3/   GX(6),GXSTR(14),HGO(6),HGOSTR(14)
      DIMENSION CGX(7,14), CHO(7,14)
C
      DATA CGX/7*0.0,0.57735026918963,6*0.0,0.77459666924148,
     1 6*0.0,0.86113631159405,0.33998104358486,5*0.0,0.90617984593866,
     2 0.53846931010568,5*0.0,0.93246951420315,0.66120938646626,
     3 0.23861918608320,4*0.0,0.94910791234276,0.74153118559939,
     4 0.40584515137740,4*0.0,0.96028985649754,0.79666647741363,
     5 0.52553240991633,0.18343464249565,3*0.0,0.96816023950763,
     6 0.83603110732664,0.61337143270059,0.32425342340381,3*0.0,
     7 0.97390652851717,0.86506336668898,0.67940956829902,
     8 0.43339539412925,0.14887433898163,2*0.0,0.97822865814606,
     9 0.88706259976809,0.73015200557405,0.51909612920681,
     1 0.26954315595234,2*0.0,0.98156063424672,0.90411725637047,
     2 0.76990267419430,0.58731795428662,0.36783149899818,
     3 0.12523340851147,0.0,0.98418305471859,0.91759839922298,
     4 0.80157809073331,0.64234933944034,0.44849275103645,
     5 0.23045831595514,0.0,0.98628380869681,0.92843488366357,
     6 0.82720131506976,0.68729290481168,0.51524863635815,
     7 0.31911236892789,0.10805494870734/
C
      DATA CHO/7*0.0,1.0,6*0.0,0.55555555555556,0.88888888888889,
     1 5*0.0,0.34785484513745,0.65214515486255,5*0.0,0.23692688505619,
     2 0.47862867049937,0.56888888888889,4*0.0,0.17132449237917,
     3 0.36076157304814,0.46791393457269,4*0.0,0.12948496616887,
     4 0.27970539148928,0.38183005050512,0.41795918367347,3*0.0,
     5 0.10122853629038,0.22238103445337,0.31370664587789,
     6 0.36268378337836,3*0.0,0.81274388361574E-1,0.18064816069485,
     7 0.26061069640293,0.31234707704000,0.33023935500126,2*0.0,
     8 0.66671344308688E-1,0.14945134915058,0.21908636251598,
     9 0.26926671931000,0.29552422471475,2*0.0,0.55668567116174E-1,
     1 0.12558036946490,0.18629021092773,0.23319376459199,
     2 0.26280454451025,0.27292508677790,0.0,0.47175336386512E-1,
     3 0.10693932599532,0.16007832854335,0.20316742672307,
     4 0.23349253653836,0.24914704581340,0.0,0.40484004765316E-1,
     5 0.92121499837728E-1,0.13887351021979,0.17814598076195,
     6 0.20781604753689,0.22628318026290,0.23255155323087,
     7 0.35119460331752E-1,0.80158087159760E-1,0.12151857068790,
     8 0.15720316715819,0.18553839747794,0.20519846372130,
     9 0.21526385346316/
C
      IF (LBAR.LE.0) GO TO 900
      IF (LBAR.GT.14) GO TO 900
```

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```
      N = (LBAR+1)/2
      NEV = 0
      IF (N.EQ.LBAR/2) NEV = 1
      DO 300 J=1,N
      HGO(J) = CHO(J,LBAR)
      GX(J) = -COX(J,LBAR)
      IF (J.EQ.N.AND.NEV.EQ.0) GO TO 300
      M = LBAR - J + 1
      GX(M) = -GX(J)
      HGO(M) = HGO(J)
  300 CONTINUE
C
  350 IF (NSTR.EQ.0) GO TO 850
C
      IF (LBARST.LE.0) GO TO 1900
      IF (LBARST.GT.14) GO TO 1900
      N = (LBARST+1)/2
      NEV = 0
      IF (N.EQ.LBARST/2) NEV = 1
      DO 800 J=1,N
      HGOSTR(J) = CHO(J,LBARST)
      GXSTR(J) = -COX(J,LBARST)
      IF (J.EQ.N .AND. NEV.EQ.0) GO TO 800
      M = LBARST - J + 1
      GXSTR(M) = -GXSTR(J)
      HGOSTR(M) = HGOSTR(J)
  800 CONTINUE
C
  850 RETURN
C
  900 WRITE(6,1000) LBAR
 1000 FORMAT (29H0THE VALUE OF LBAR IS INVALID/
     1   8H0LBAR = I4)
      LBAR = 0
      RETURN
C
 1900 WRITE(6,2000) LBARST
 2000 FORMAT (31H0THE VALUE OF LBARST IS INVALID/
     1   10H0LBARST = I4)
      LBARST = 0
      RETURN
C
      END
```

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```
      SUBROUTINE LIST1
C
C     THIS SUBROUTINE PRINTS AND/OR CHECKS CRITICAL STRAINS, STRESS AND
C     DISPLACEMENTS FOR THE MULTILAYER (NDERV=1) METHOD.
C
C     KZ- PRINT CODE
C       0, RETURN
C       1, COMPUTATIONS ONLY
C       2, DON'T CHECK MAX BUT DO PRINT
C       3, CHECK MAX AND PRINT
C     NUSE - USE CODE FOR SPATIAL POINTS.
C       0, NO USE.
C       1, PRINT ONLY.
C       2, INTEGRATION PURPOSES ONLY.
C       3, PRINTOUT, TOO.
      COMMON/CBLK1/   A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1   MBAR,MBSTR,MG,MGM(13),MGMB,NGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2   NBNB,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK8/   NU,P(361),RA(23,23)
      COMMON/CBLK9/   BTL(8),BXL(8),BXLST(8),CCRIT(8),CINST(3),ET(8),
     1   EX(8),GXT(8),NLZ(16),NREG,NTESO,NZP,SAC(8),SAT(8),SMAX,
     2   TCRIT(8),THNU(8),TMAX,XXNU(8),ZC(40),ZCSTR(2)
      COMMON/CBLK10/ DWB(361),DWG(361),DWO(361),         U(361),
     1   UB(361),UG(361),V(361),VB(361),VG(361),W(361),WB(361),
     2   WBB(361),WG(361),WGB(361),WGG(361)
      COMMON /CBLK14/ NBUSE(23,23),NPC,C1,C2,C3,C4,C5,C6,C7,
     1  DELX,DELT,    WGGG(44),WBBB(44),WGGB(44),WGBB(44),
     2  VRX(44),VRT(44),RR(4),ENX(44),ENT(44),NKP,KPG(46),KPB(46)
      COMMON/CNOVA/   CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1   KDAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NDBUG,NMASS,NTRIAL,
     2  PD(40),PDAM,PPP,PRINT,PER,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3   ZZ1(3)
      COMMON          CN10,CN11,CN8,CN3,EPBD(1805),EPBOST(1380),ETT,EXT,
     1   EXX,EXXSTR,INZ(2),INZSTR(2),KSUMA(361),KSUMAS(230),KY(1805),
     2   KYSTR(1380),NUSE(23,23),STT(1805),SXT(1805),SXX(1805),
     3   SXXSTR(1380),S1A(361),S2A(361),S3A(361),S4A(361),S5A(361),
     4   S6A(361),S7A(230),S8A(230),UU(13,13),VV(13,13),WW(13,13),
     5   XB(23),XG(23),XKTT,XKXT,XKXX,XKXXST,X1A(361),X2A(361),X3A(361),
     6   X4A(361),X5A(361),X6A(361),X7A(230),X8A(230),ZA(2),ZASTR(2),
     7   ZB(2),ZBSTR(2),ZF(6),ZFSTR(14),ZG(6),ZGSTR(14),ZH(6),ZHSTR(14)
C
      DATA FL1/2H  /,FL2/2H */
      DATA FLSTR/2H S/,ZERO/0.0/
C
      IF (KZ.EQ.0) GO TO 1000
      IF (KZ.EQ.1) GO TO 10
      IF (NCALL.EQ.0) WRITE (6,5000) TIME
      WRITE (6,5100)
      DO 5 I=1,MG
      M = MGM(I)
      DO 5 J=1,MB
```

```
      N = NBN(J)
      IF (MUSE(J,I).EQ.0) GO TO 5
      WRITE(6,5200) M,N,UU(J,I),VV(J,I),WW(J,I)
    5 CONTINUE
      IF (NKP.EQ.0) GO TO 1000
      IF (NPLT.EQ.0) WRITE(6,5800)
      IF (NPLT.EQ.1) WRITE(6,5300)
   10 M=0
      LSTR=0
      DO 750 I=1,NST
      X = XG(I)
      DO 700 J=1,NBT
      NNUSE = NUSE(J,I)
      IF (NNUSE.EQ.0) GO TO 700
      M = M + 1
      IMASTR = 0
      IF (NSTR.EQ.0) GO TO 30
      DO 20  L=1,NSTR
      IF (LOCSTR(L).NE.J) GO TO 20
      IMASTR=1
      LSTR=LSTR+1
   20 CONTINUE
   30 IF (NNUSE.LT.2) GO TO 700
      IF (KZ.EQ.2 .AND. NNUSE.EQ.2) GO TO 700
      TH=X3(J)
      EXX = X1A(M)
      ETT = X2A(M)
      EXT = X3A(M)
      XKXX = X4A(M)
      XKTT = X5A(M)
      XKXT = X6A(M)
      IF (IMASTR.EQ.0) GO TO 100
      EXXSTR = X7A(LSTR)
      XKXXST = X8A(LSTR)
  100 DO 650 K=1,NZP
      II = NLZ(K)
      S2 = ZC(K)/A
      X1 = EXX + S2*XKXX
      X2 = ETT + S2*XKTT
      X3 = EXT + S2*XKXT
      SIGXX = BXL(II)*(X1 + THNU(II)*X2)
      SIGTT = BTL(II)*(X2 + XXNU(II)*X1)
      SIGXT = GXT(II)*X3
      IF (IMASTR.EQ.0) GO TO 500
      S4 = ZCSTR(K) / A
      X4 = EXXSTR + S4*XKXXST
      SIGXXS = BXLST(II)*X4
C     PRINCIPAL STRESSES.
  500 SIG = SQRT(.25*(SIGXX - SIGTT)**2 + SIGXT**2)
      S1 = (SIGXX + SIGTT)*.5
      SIG1 = S1 + SIG
```

```
      SIG2 = S1 - SIG
  600 FLAG = FL1
      IF (SIG1.GT.SAT(II)) FLAG = FL2
      IF (SIG2.LT.-SAC(II)) FLAG = FL2
      WRITE (6,5400) FLAG,X,TH,ZC(K),X1,X2,X3,SIGXX,SIGTT,SIGXT
      IF (IMASTR.NE.0)
     1   WRITE(6,5400) FLSTR,X,TH,ZCSTR(K),X4,ZERO,ZERO,SIGXXS,ZERO,ZERO
  650 CONTINUE
  700 CONTINUE
  750 CONTINUE
      IF (KZ.LT.2) GO TO 1000
C
      WRITE (6,6000)
      DO 770 I=1,MBAR
      X = XG(I)
      DO 770 J=1,NBAR
      NBC = NBUSE(J,I)
      IF (NBC.EQ.0.OR.NBC.GT.100) GO TO 770
      Y = XB(J)
      IF (NBC.GT.0) GO TO 760
      NC = -NBC
      WRITE (6,6100) X,Y,VPX(NC),ENX(NC)
      GO TO 770
  760 WRITE (6,6100) X,Y,VRT(NBC),ENT(NBC)
  770 CONTINUE
      IF (NBND.EQ.1) GO TO 790
      WRITE (6,6200)
      DO 780 I=1,NPC
      X = XG(1)
      IF (I.GT.2) X = XG(MBAR)
      Y = XB(1)
      IF (I.EQ.2.OR.I.EQ.4) Y = XB(NBAR)
      WRITE (6,6100) X,Y,PP(I)
  780 CONTINUE
C
  790 IF (NPLT.EQ.0) WRITE (6,5700)
      IF (NPLT.EQ.1) WRITE (6,5500)
      KKK = 0
      DO 910 I=1,NGT
      X = XG(I)
      DO 810 J=1,NBT
      NNUSE = NUSE(J,I)
      IF (NNUSE.EQ.0) GO TO 800
      KKK = KKK + 1
      IF (NNUSE.LE.2) GO TO 800
      IF (NU.EQ.0) PPP = P(KKK)
      UF = A*U(KKK)
      VF = A*V(KKK)
      WF = A*W(KKK)
      WRITE (6,5600) X,XB(J),UF,VF,WF,PPP
C
```

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```
  800 CONTINUE
  900 CONTINUE
 1000 RETURN
C
 5000 FORMAT (//1H0,3HT =,E15.7,4H SEC)
 5100 FORMAT (1H0,2X,5HGAMMA,3X,4HBETA,8X,3HURS,13X,3HVRS,13X,3HWRS)
 5200 FORMAT (I5,I7,2X,3E16.7)
 5300 FORMAT (1H0,7X,1HX,3X,5H BETA,5X,1HZ,10X,3HEXX,12X,3HETT,12X,
     1   3HEXT,9X,8HSIGMA XX,7X,8HSIGMA TT,7X,8HSIGMA XT/
     2   6X,4H(IN),2X,5H(DEG),3X,4H(IN),6X,7H(IN/IN),8X,7H(IN/IN),
     3   8X,7H(IN/IN),9X,5H(PSI),10X,5H(PSI),10X,5H(PSI))
 5400 FORMAT (1X,A2,2X,F5.2,2X,F5.2,1X,F7.4,6E15.6)
 5500 FORMAT (1H0,7X,5HX(IN),9X,10H BETA(DEG),8X,5HU(IN),
     1   11X,5HV(IN),11X,5HW(IN),6X,14HPRESSURE (PSI))
 5600 FORMAT (1X,6E16.7)
 5700 FORMAT (1H0,7X,5HX(IN),12X,5HY(IN),10X,5HU(IN),
     1   11X,5HV(IN),11X,5HW(IN),6X,14HPRESSURE (PSI))
 5800 FORMAT (1H0,7X,1HX,6X,1HY,5X,1HZ,10X,3HEXX,12X,3HETT,12X,
     1   3HEXT,9X,8HSIGMA XX,7X,8HSIGMA TT,7X,8HSIGMA XT/
     2   6X,4H(IN),3X,4H(IN),3X,4H(IN),6X,7H(IN/IN),8X,7H(IN/IN),
     3   8X,7H(IN/IN),9X,5H(PSI),10X,5H(PSI),10X,5H(PSI))
 5900 FORMAT(27H0DEFLECTION AT CENTER,IN = E15.8)
 6000 FORMAT (51H0REACTIVE FORCES PER UNIT LENGTH ALONG EDGE (LB/IN)/
     1   6X,1HX,8X,1HY,9X,1HV,14X,1HN)
 6100 FORMAT (2F8.3,2E15.6)
 6200 FORMAT (33H0REACTIVE FORCES AT CORNERS (LBS))
      END
```

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```
      SUBROUTINE LIST2
C     THIS SUBROUTINE PRINTS AND/OR CHECKS STRAINS, STRESSES, AND
C       DISPLACEMENTS FOR THE SINGLE LAYER (NDERV=2) METHOD.
C
C     KZ- PRINT CODE
C         0, RETURN
C       1, COMPUTATIONS ONLY
C         2, DON'T CHECK MAX BUT DO PRINT
C         3, CHECK MAX AND PRINT
C     NUSE - USE CODE FOR SPATIAL POINTS.
C       0, NO USE.
C       1, PRINT ONLY.
C       2, INTEGRATION PURPOSES ONLY.
C       3, PRINTOUT, TOO.
C
      COMMON/CBLK1/   A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1   MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2   NBNB,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK7/   BSTR,CN1,CN12,CN13,CN2,CN2STR,CN3,CN4,CN5,CN6,CN7,
     1   FL,FP,FPO,FPP,FPPSTR,H,HSTR,IFIRST,JFIRST,JSTRFT,LC,LCMAX,
     2   LCMAXS,LCSTR,NFLP,SIGO,SIGO2,TNU,TNUSQ
      COMMON/CBLK8/   NU,P(361),RA(23,23)
      COMMON/CBLK9/   BTL(8),BXL(8),BXLST(8),CCRIT(8),CINST(3),ET(8),
     1   EX(8),GXT(8),NLZ(15),NREG,NTECO,NZP,SAC(8),SAT(8),SMAX,
     2   TCRIT(8),THNU(8),TMAX,XXNU(8),ZC(40),ZCSTR(2)
      COMMON/CBLK10/  DWB(361),DWG(361),DWO(361),        U(361),
     1   UB(361),UG(361),V(361),VB(361),VG(361),W(361),WB(361),
     2   WBB(361),WG(361),WGB(361),WGG(361)
      COMMON /CBLK14/ NRUSE(23,23),NRC,C1,C2,C3,C4,C5,C6,C7,
     1  DELX,DELT,     WGGG(44),WBBB(44),WGGB(44),WGBB(44),
     2  VPX(44),VPT(44),RR(4),ENX(44),ENT(44),NKP,KPG(46),KPB(46)
      COMMON/CNOVA/   CRIT(5),DELTIM,GAMMA(41),ICOMP,INPUT,KALT,KB,
     1   KDAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NOBUG,NMASS,NTRIAL,
     2  PB(40),PDAM,PPP,PRINT,REP,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3   ZZ1(2)
      COMMON          CN10,CN11,CN8,CN9,EPBO(1805),EPBOST(1380),ETT,EXT,
     1   EXX,EXXSTR,INZ(2),INZSTR(2),KSUMA(361),KSUMAS(230),KY(1805),
     2   KYSTR(1380),NUSE(23,23),STT(1805),SXT(1805),SXX(1805),
     3   SXXSTR(1380),S1A(361),S2A(361),S3A(361),S4A(361),S5A(361),
     4   S6A(361),S7A(230),S8A(230),UU(13,13),VV(13,13),WW(13,13),
     5   XB(23),XG(23),XKTT,XKXT,XKXX,XKXXST,X1A(361),X2A(361),X3A(361),
     6   X4A(361),X5A(361),X6A(361),X7A(230),X8A(230),ZA(2),ZASTR(2),
     7   ZB(2),ZBSTR(2),ZF(5),ZFSTR(14),ZG(6),ZGSTR(14),ZH(6),ZHSTR(14)
C
      DATA FL1/2H  /,FL2/2H */
      DATA FLSTR/2H S/,ZERO/0.0/
C
      IF (KZ.EQ.0) GO TO 1000
      IF (KZ.EQ.1) GO TO 10
      IF (NCALL.EQ.0) WRITE (6,5000) TIME
      WRITE (6,5100)
```

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```
      DO 5 I=1,MG
      M = MGM(I)
      DO 5 J=1,MR
      IF (MUSE(J,I).EQ.0) GO TO 5
      N = NRM(J)
      WRITE(6,5200) M,N,UU(J,I),VV(J,I),WW(J,I)
    5 CONTINUE
      IF (NKP.EQ.0) GO TO 1000
      IF (NPLT.EQ.0) WRITE(6,5300)
      IF (NPLT.EQ.1) WRITE(6,5300)
   10 M=0
      MSTR=0
      DO 300 I=1,NST
      X = XS(I)
      DO 200 J=1,NRT
      NNUSE = NUSE(J,I)
      IF (NNUSE.EQ.0) GO TO 200
      M = M + 1
      IMASTR = 0
      IF (MSTR.EQ.0) GO TO 20
      DO 15  LL=1,MSTR
      IF (LOCSTR(LL).NE.J) GO TO 15
      IMASTR = 1
      MSTR = MSTR + 1
   15 CONTINUE
   20 IF (NNUSE.LT.2) GO TO 200
      IF (KZ.EQ.2.AND.NNUSE.EQ.2) GO TO 200
      JI = LBAR*(M-1)
      TH=X3(J)
      EXX = X1A(M)
      ETT = X2A(M)
      EXT = X3A(M)
      XKXX = X4A(M)
      XKTT = X5A(M)
      XKXT = X6A(M)
      IF (IMASTR.EQ.0) GO TO 30
      JISTR = LBARST * (MSTR-1)
      EXXSTR = X7A(MSTR)
      XKXXST = X8A(MSTR)

   30 DO 100 KK=1,2
      K = INZ(KK)
      L = JI + K
      S2 = ZA(KK)
      FLAG=FL1
      IF (NFLP.EQ.1.AND.EPBD(L).GT.SIGO2) FLAG = FL2
      X1 = EXX + S2*XKXX
      X2 = ETT + S2*XKTT
      X3 = EXT + S2*XKXT
      IF (IMASTR.EQ.0) GO TO 40
      KSTR = INZSTR(KK)
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```
      LSTR = JISTR + KSTR
      S4 = ZASTR(KK)
      X4 = FXXSTR + S4*XKXXST
   40 IF (NFLR.EQ.2) GO TO 50
      SIG1 = S1A(M) + S2*S4A(M)
      SIG2 = S2A(M) + S2*S5A(M)
      SIG3 = S3A(M) + S2*S6A(M)
      IF (IMASTR.NE.0)  SIG4 = S7A(MSTR) + S4*S8A(MSTR)
      GO TO 60
   50 SIG1 = SXY(L)
      SIG2 = STT(L)
      SIG3 = SXT(L)
      IF (IMASTR.NE.0) SIG4 = SXXSTR(LSTR)
   60 IF (NMUSE.EQ.2) GO TO 100
      IF (KZ.EQ.1) GO TO 100
      WRITE (6,5400) FLAG,X,TH,ZB(KK),X1,X2,X3,SIG1,SIG2,SIG3,KY(L)
      IF (IMASTR.NE.0)  WRITE (6,5400)
     1     FLSTR,X,TH,ZBSTR(KK),X4,ZERO,ZERO,SIG4,ZERO,ZERO,KYSTR(LSTR)
  100 CONTINUE
  200 CONTINUE
  300 CONTINUE
C
      IF (KZ.LT.2) GO TO 1000
C
      WRITE (6,6000)
      DO 370 I=1,MBAR
      X = XG(I)
      DO 370 J=1,NBAR
      NBC = NBUSE(J,I)
      IF (NBC.EQ.0.OR.NBC.GT.100) GO TO 370
      Y = XB(J)
      IF (NBC.GT.0) GO TO 360
      NC = -NBC
      WRITE (6,6100) X,Y,VRX(NC),FNX(NC)
      GO TO 370
  360 WRITE (6,6100) X,Y,VRT(NBC),FNT(NBC)
  370 CONTINUE
      IF (NBND.EQ.1) GO TO 390
      WRITE (6,6200)
      DO 380 I=1,NBD
      X = XG(1)
      IF (I.GT.2) X = XG(MBAR)
      Y = XB(1)
      IF (I.EQ.2.OR.I.EQ.4) Y = XB(NBAR)
      WRITE (6,6100) X,Y,RR(I)
  380 CONTINUE
C
  390 IF (NPLT.EQ.0) WRITE(6,5700)
      IF (NPLT.EQ.1) WRITE(6,5500)
      KKK=0
      DO 500 I=1,NGT
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```
      X = XG(I)
      DO 400 J=1,NBT
      NNUSE = NUSE(J,I)
      IF (NNUSE.EQ.0) GO TO 400
      KKK = KKK + 1
      IF (NNUSE.LE.2) GO TO 400
      IF (NU.EQ.0) PPP = P(KKK)
      UF = A*U(KKK)
      VF = A*V(KKK)
      WF = A*W(KKK)
      WRITE (6,5600) X,XB(J),UF,VF,WF,PPP
  400 CONTINUE
  500 CONTINUE
C
 1000 RETURN
C
 5000 FORMAT (//1H0,3HT =,E15.7,4H SEC)
 5100 FORMAT (1H0,2X,5HGAMMA,3X,4HBETA,8X,3HURS,13X,3HVRS,13X,3HWRS)
 5200 FORMAT (I5,I7,2X,3E16.7)
 5300 FORMAT (1H0,7X,1HX,3X,5H BETA,5X,1HZ,10X,3HEXX,12X,3HETT,12X,
     1  3HEXT,9X,8HSIGMA XX,7X,8HSIGMA TT,7X,8HSIGMA XT,3X,6HREGION/
     2  6X,4H(IN),2X,5H(DEG),3X,4H(IN),6X,7H(IN/IN),8X,7H(IN/IN),
     3  8X,7H(IN/IN),9X,5H(PSI),10X,5H(PSI),10X,5H(PSI))
 5400 FORMAT (1X,A2,2X,F5.2,2X,F5.2,1X,F7.4,6E15.6,I4)
 5500 FORMAT (1H0,7X,5HX(IN),9X,10H BETA(DEG),8X,5HU(IN),
     1  11X,5HV(IN),11X,5HW(IN),6X,14HPRESSURE (PSI))
 5600 FORMAT (1X,6E16.7)
 5700 FORMAT (1H0,7X,5HX(IN),12X,5HY(IN),10X,5HU(IN),
     1  11X,5HV(IN),11X,5HW(IN),6X,14HPRESSURE (PSI))
 5800 FORMAT (1H0,7X,1HX,6X,1HY,6X,1HZ,10X,3HEXX,12X,3HETT,12X,
     1  3HEXT,9X,8HSIGMA XX,7X,8HSIGMA TT,7X,8HSIGMA XT,3X,6HREGION/
     2  6X,4H(IN),3X,4H(IN),3X,4H(IN),6X,7H(IN/IN),8X,7H(IN/IN),
     3  8X,7H(IN/IN),9X,5H(PSI),10X,5H(PSI),10X,5H(PSI))
 6000 FORMAT (51H0REACTIVE FORCES PER UNIT LENGTH ALONG EDGE (LB/IN)/
     1  6X,1HX,8X,1HY,9X,1HV,14X,1HN)
 6100 FORMAT (2F8.3,2E15.6)
 6200 FORMAT (33H0REACTIVE FORCES AT CORNERS (LBS))
      END
```

```
      SUBROUTINE PINIT(M)
      COMMON/CNOVA/  CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1   KDAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NDBUG,NMASS,NTRIAL,
     2  PR(40),PDAM,PPP,PRINT,RER,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3   ZZ1(3)
      COMMON /CLOAD/ PP1,PPO,TTO,TPRIME,AA,ANN,OTT1,OTTO,AZ,
     1  JL,NTIME,NLOAD,PT(20),TT(20), ZEE,PHI,Q1,Q2,VS,
     2  DFT(10,10),NPX,NPY,DTIM,PPT(6,10,10),XP(10),YP(10),
     3  IXI(23),JYJ(23),JLT(10,10),PRTT(10,10),DX1(23),DY1(23)
      COMMON/CBLK1/   A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1    MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2    NBNB,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK8/   NU,P(361),RA(23,23)
      COMMON          CN10,CN11,CN8,CN9,EPRO(1805),EPROST(1380),ETT,EXT,
     1    EXX,EXXSTR,INZ(2),INZSTR(2),KSUMA(361),KSUMAS(231),KY(1805),
     2    KYSTR(1380),NUSE(23,23),STT(1805),SXT(1805),SXX(1805),
     3    SXXSTR(1380),S1A(361),S2A(361),S3A(361),S4A(361),S5A(361),
     4    S6A(361),S7A(230),S8A(230),UU(13,13),VV(13,13),WW(13,13),
     5    XD(23),XG(23),XKTT,XKXT,XKXX,XKXXST,X1A(361),X2A(361),X3A(361),
     6    X4A(361),X5A(361),X6A(361),X7A(230),X8A(230),ZA(2),ZASTR(2),
     7    ZB(2),ZBSTR(2),ZF(6),ZFSTR(14),ZG(6),ZGSTR(14),ZH(6),ZHSTR(14)
      DIMENSION QQ1(3),QQ2(3)
      DATA QQ1/87.E-6, 90.E-6, 84.E-6/, QQ2/0.0686, 0.1127, 0.1275/
C
      IF (M.EQ.1) GO TO 200
      IF (KDS.EQ.2) GO TO 150
C
C     STATIC
C
      READ (5,2000) PS
      WRITE(6,2200) PS
      NU=1
      PPP=PS
  150 RETURN
C
C     DYNAMIC
C
  200 IF (KDS.EQ.1) GO TO 400
      READ (5,1000) NLOAD
      WRITE (6,2400) NLOAD
      GO TO (600,800,250,500), NLOAD
  250 READ (5,2000) PP1,PPO,TTO,TPRIME,AA,ANN
      WRITE(6,2300) PP1,PPO,TTO,TPRIME,AA,ANN
      NU=1
      IF (TPRIME.EQ.0.0) GO TO 300
      PPRIME=PPO*(1.0 - TPRIME/TTO)**ANN
      PPRIME = PPRIME*EXP(-AA*TPRIME/TTO)
      TT1=TPRIME*PP1/(PP1-PPRIME)
      OTT1=1.0/TT1
  300 OTTO=1.0/TTO
      AZ=A1*OTTO
```

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```
  400 RETURN
C
  500 READ (5,1000) NTIME
      READ (5,2100) (TT(I),PT(I),I=1,NTIME)
      WRITE (6,2500) NTIME,(TT(I),PT(I),I=1,NTIME)
      NU = 1
      JL = 2
      RETURN
C     EGLIN SYMMETRIC, NONUNIFORM LOAD ON FLAT PLATE.
  600 VS = 5.88E4
      READ (5,2000) ZEE,PHI
      WRITE (6,2600) ZEE,PHI
      X0 = XG(NG)
      Y0 = YB(NB)
      DO 700 I=1,NGT
      X = XG(I) - X0
      DO 700 J=1,NBT
      Y = YB(J) - Y0
  700 RA(J,I) = SQRT(X**2 + Y**2 + ZEE**2)
      IPHI = 1
      IF (PHI.GT.0.0) IPHI = 2
      IF (PHI.GT.30.0) IPHI = 3
      Q1 = QQ1(IPHI)
      Q2 = QQ2(IPHI)
      NU = 0
      RETURN
C
  800 READ (5,1000) NPX,NPY,NTIME
      READ (5,2000) DTIM
      WRITE (6,2700) NPX,NPY,NTIME,DTIM
      READ (5,2000) (XP(I),I=1,NPX)
      WRITE (6,3100) (XP(I),I=1,NPX)
      READ (5,2000) (YP(J),J=1,NPY)
      WRITE (6,3200) (YP(J),J=1,NPY)
      WRITE (6,3300)
      DO 820 I=1,NPX
      READ (5,2000) (DET(J,I),J=1,NPY)
  820 WRITE (6,2800) (DET(J,I),J=1,NPY)
      WRITE (6,2900)
      DO 840 I=1,NPX
      DO 840 J=1,NPY
      READ (5,2000) (PPT(K,J,I),K=1,NTIME)
  840 WRITE (6,3000) (PPT(K,J,I),K=1,NTIME)
C     SPATIAL INTERPOLATION-EXTRAPOLATION.  INDICES ARE LOWER BOUND.
      DO 910 I=1,NGT
      DO 860 III = 1,NPX
      IF (XP(III).GT.XG(I)) GO TO 880
  860 CONTINUE
      III = NPX
  880 IF (III.GT.1) III = III - 1
      DXI(I) = (XG(I) - XP(III))/(XP(III+1) - XP(III))
```

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```
  900 IXI(I) = III
      DO 950 J = 1,NBI
      DO 920 JJJ = 1,NPY
      IF (YP(JJJ).GT.XB(J)) GO TO 940
  920 CONTINUE
      JJJ = NPY
  940 IF (JJJ.GT.1) JJJ = JJJ - 1
      DY1(J) = (XB(J) - YP(JJJ))/(YP(JJJ+1) - YP(JJJ))
  950 JYJ(J) = JJJ
      NU = 0
      DO 980 I=1,NPY
      DO 980 J=1,NPY
  980 JLT(J,I) = 2
      RETURN

 1000 FORMAT (6I12)
 2000 FORMAT(5F12.1)
 2100 FORMAT (2F12.1)
 2200 FORMAT(24H0STATIC PRESSURE, PSI = E15.6)
 2300 FORMAT(23H0DYNAMIC LOAD CONSTANTS/
     1       11H  PP1      = E15.6/
     1       11H  PP0      = E15.6/
     1       11H  TT0      = E15.6/
     1       11H  TPRIME   = E15.6/
     1       11H  AA       = E15.6/
     1       11H  ANN      = E15.6)
 2400 FORMAT (21H0DYNAMIC LOAD OPTION I4)
 2500 FORMAT (18H0NUMBER OF TIMES = I4/28H     TIME, SEC  PRESSURE, PSI/
     1   (2F15.6))
 2600 FORMAT (41H0DYNAMIC LOAD CONSTANTS - FLAT PLATE ONLY/
     1  14H  ZEE (IN)   = E15.6/ 14H  PHI (DEG) = E15.6)
 2700 FORMAT (23H0DYNAMIC LOAD CONSTANTS/
     1  12H   NPX     = I3/12H   NPY     = I3/
     2  12H   NTIME   = I3/12H   DTIM    = E15.6)
 2800 FORMAT (5X,5E15.6)
 2900 FORMAT (12H0PRESSURES =)
 3000 FORMAT (5X,6E15.6)
 3100 FORMAT (19H0X-POSITIONS (IN) =/(5X,5E15.6))
 3200 FORMAT (26H0Y-POSITIONS (IN OR DEG) =/(5X,5E15.6))
 3300 FORMAT (20H0DELAY TIMES (SEC) =)
      END
```

```
      SUBROUTINE PRESS
      COMMON/CNOVA/   CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1   KBAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NDBUG,NMASS,NTRIAL,
     2  PB(40),PDAM,PPP,PPIN1,RER,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3   ZZ1(2)
      COMMON /CLOAD/ PP1,PP0,TI0,TPRIME,AA,ANN,OTT1,OTT0,AZ,
     1  JL,NTIME,NLOAD,PT(20),TT(20), ZEE,PHI,D1,D2,VS,
     2  DFI(10,10),NPX,NPY,DTIM,PRI(5,10,10),XP(10),YP(10),
     3  IXI(23),JYJ(23),JLT(10,10),PRTT(10,10),DX1(23),DY1(23)
      COMMON/CBLK1/   A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1   MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2   NBNB,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK8/   NJ,P(361),RA(23,23)
      COMMON          CN10,CN11,CN8,CN9,EPPD(1805),EPPDST(1380),ETT,EXT,
     1   EXY,EXYSTR,INZ(2),INZSTR(2),KSUMA(361),KSUMAS(230),KY(1805),
     2   KYSTR(1380),NUSE(23,23),STT(1805),SXT(1805),SXX(1805),
     3   SXYSTR(1380),S1A(361),S2A(361),S3A(361),S4A(361),S5A(361),
     4   S6A(361),S7A(230),S8A(230),UU(13,13),VV(13,13),WW(13,13),
     5   XB(23),XG(23),XKTT,XKXT,XKXX,XKXXST,X1A(361),X2A(361),X3A(361),
     6   X4A(361),X5A(361),X6A(361),X7A(230),X8A(230),ZA(2),ZASTR(2),
     7   ZB(2),ZBSTR(2),ZF(6),ZFSTR(14),ZG(6),ZGSTR(14),ZH(6),ZHSTR(14)
C
      IF (NCALL.GT.0) GO TO 1000
      ZZ= 1.0/RTRIAL(1)
      GO TO (400,800,50,220), NLOAD
   50 IF (TIME.GE.TPRIME) GO TO 100
      PPP=ZZ*PP1*(1.0 - TIME*OTT1)
      IF (PPP.LT.0.0) PPP=0.0
      GO TO 1000
  100 IF (TIME.GE.TI0) GO TO 200
      PPP=PP0*(1.0 - TIME*OTT0)**ANN
      PPP=ZZ*PPP*EXP(-AZ*TIME)
      GO TO 1000
  200 PPP=0.0
      GO TO 1000
C
  220 DO 240 J=JL,NTIME
      IF (TIME.LE.TT(J)) GO TO 260
  240 CONTINUE
      WRITE (6,250) TIME,TT(NTIME)
  250 FORMAT (32H ** WARNING - TIME EXCEEDS TABLE, 2E15.6)
      J = NTIME
  260 JL = J
      PPP = PT(J-1) + (TIME - TT(J-1))*(PT(J) - PT(J-1))/
     1  (TT(J) - TT(J-1))
      PPP = ZZ*PPP
      GO TO 1000
C
  400 DUM = TIME + ZEE/VS
      TD = D1 - D2*DUM
      PM = 434.95*DUM**(-.29)
```

```
      K = 0
      DO 600 I=1,NGT
      DO 600 J=1,NRT
      IF (NUSE(J,I).EQ.0) GO TO 600
      K = K + 1
      RRR = R1(J,I)
      TSTAR = (RRR - ZEE)/VS
      PPP = 0.0
      IF (TSTAR.GT.TIME + 1.0E-12) GO TO 500
      IF (TIME-TSTAR.GT.TD) GO TO 500
      FAC = (TSTAR - TIME)/TD
      CALPH = ZEE/RRR
      PPP = PM*CALPH*(1.0 + FAC)
  500 P(K) = PPP*ZZ
  600 CONTINUE
      GO TO 1000
C
C     INTERPOLATE ON TIME.
  800 DO 860 I=1,NPX
      DO 860 J=1,NPY
      PPP = 0.0
      DETT = DET(J,I)
      IF (TIME.LT.DETT) GO TO 860
      JL = JLT(J,I)
      DO 820 K=JL,NTIME
      KK=K
      IF (TIME.LE.DETT + DTIM*FLOAT(K-1)) GO TO 840
  820 CONTINUE
      JLT(J,I) = NTIME
      PPP = PRT(NTIME,J,I)
      GO TO 860
  840 JL = KK
      P1 = PRT(JL-1,J,I)
      T1 = DETT + DTIM*FLOAT(JL-2)
      PPP = P1 + (TIME - T1)*(PRT(JL,J,I) - P1)/DTIM
      JLT(J,I) = JL
  860 PRTT(J,I) = PPP
C     INTERPOLATE SPATIALLY.
      K = 0
      DO 880 I=1,NGT
      II = IXI(I)
      DX = DX1(I)
      DO 880 J=1,NRT
      IF (NUSE(J,I).EQ.0) GO TO 880
      K = K + 1
      JJ = JYJ(J)
      DY = DY1(J)
      P1 = PRTT(JJ,II) + DY*(PRTT(JJ+1,II) - PRTT(JJ,II))
      P2 = PRTT(JJ,II+1) + DY*(PRTT(JJ+1,II+1) - PRTT(JJ,II+1))
      PPP = P1 + DX*(P2 - P1)
      P(K) = PPP*ZZ
```

```
  880 CONTINUE
C
 1000 RETURN
      END
```

```
      SUBROUTINE PROP

      COMMON /FIRST/ ICOUNT
      COMMON/CBLK1/  A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1   MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2   NBNB,NBT,NOBRV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK2/  BSTR(23),CC1(13),CC2(13),CC5(13),CC6(13),
     1   CK(6),COSB(299),COSG(299),COS2B(299),COS2G(299),DPRT,DPRT1,
     2   FP1(299),FP2(299),FP3(299),FP4(13,2),FP5(299),FP5(299),
     3   FP7(299),FP8(13,2),
     3   GAM(23),KC,PIMA(23),PINA(23),SINB(299),SING(299),
     4   SIN2B(299),SIN2G(299),XJ,XJ2,XJ3,XJ4,XJ5,XL,XLP,XLP1,XLP2,
     5   XLP3,XL1,XL2,XL3,XL4,XL5,XL7,STRCN1,STRCN2
      COMMON/CBLK3/  GX(6),GXSTR(14),HGO(6),HGOSTR(14)
      COMMON/CBLK4/  NY2,VXO(147),XY(147),YY(147),
     1   AAU(49,49),AAW(49,49),BBU(49),BBW(49),IPU(49),IPW(49)
      COMMON/CBLK5/  FM(8),FPP(147),FG(13,13),HM(20),MOUT(169),
     1   NOUT(169),PHOM(8),U1(13,13),V1(13,13),W1(13,13)
      COMMON/CBLK7/  BSTR,CN1,CN12,CN13,CN2,CN2STR,CN3,CN4,CN5,CN6,CN7,
     1   FL,FP,EPO,EPP,EPPSTR,H,HSTR,IFIRST,JFIRST,JSTRFT,LC,LCMAX,
     2   LCMAXS,LCSTR,NFLP,SIGO,SIGO2,TNU,TNUSQ
      COMMON/CBLK8/  NU,P(361),PA(23,23)
      COMMON/CBLK9/  BTL(8),BXL(8),BXLST(8),CCRIT(8),CINST(3),ET(8),
     1   EX(8),GXT(8),NLZ(16),NREG,NTECO,NZP,SAC(8),SAT(8),SMAX,
     2   TCRIT(8),THNU(8),TMAX,XXNU(8),ZC(40),ZCSTR(2)
      COMMON/CBLK10/ DWB(361),DWG(361),DWO(361),        U(361),
     1   UB(361),UG(361),V(361),VB(361),VG(361),W(361),WB(361),
     2   WBB(361),WG(361),WGB(361),WGG(361)
      COMMON/CBLK11/ CM11,CM11ST,CM12,CM22,CM33,DM11,DM11ST,DM12,DM22,
     1   DM33,FM11,FM12,FM22,FM33
      COMMON/CBLK13/ DC,EC,EPSIF,GC,HBAR,NL,NNOUT,RHO,THETA0
      COMMON /CBLK14/ NBUSE(23,23),NRC,C1,C2,C3,C4,C5,C6,C7,
     1 DELX,DELT,    WGGG(44),WBBB(44),WGGB(44),WGBB(44),
     2 VPX(44),VPT(44),PR(4),ENX(44),ENT(44),NKP,KPG(46),KPB(46)
      COMMON/CNOVA/  CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1   KDAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NOBJG,NMASS,NTRIAL,
     2 PD(40),PDAM,PPP,PRINT,RER,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3   Z71(2)
      COMMON         CN10,CN11,CN8,CN9,EPRO(1805),EPROST(1380),ETT,EXT,
     1   EXY,EXYSTR,INZ(2),INZSTR(2),KSUMA(361),KSUMAS(230),KY(1805),
     2   KYSTR(1380),NUSE(23,23),STT(1805),SXT(1805),SXX(1805),
     3   SXYSTR(1380),S1A(361),S2A(361),S3A(361),S4A(361),S5A(361),
     4   S6A(361),S7A(230),S8A(230),UU(13,13),VV(13,13),WW(13,13),
     5   YB(23),XG(23),XKTT,XKXT,XKXX,XKXXST,X1A(361),X2A(361),X3A(361),
     6   X4A(361),X5A(361),X6A(361),X7A(230),X8A(230),ZA(2),ZASTR(2),
     7   ZB(2),ZBSTR(2),ZF(6),ZFSTR(14),ZG(6),ZGSTR(14),ZH(6),ZHSTR(14)

      IF (NCALL.EQ.0) GO TO 5700
      IF (NCALL.EQ.1) GO TO 5450
      PI=3.14159265358978
      EPRS=1.0E-5
```

```
      IFIRST=0
      JFIRST = 0
      JSTRFT = 0
      NU = 1
C
      CALL DSET1
C
      CALL DSET2
      IF (KERR.GT.0) GO TO 6300
C
      CALL DSET3
C
      DO 5300 M=1,MG
      DO 5300 N=1,MR
      U1(N,M)=0.0
      V1(N,M)=0.0
      W1(N,M)=0.0
 5300 CONTINUE
      DO 5400 J=1,NY2
      XX(J)=0.0
 5400 ERR(J)=ERRS
      GO TO 5900
C
C
 5450 IF (KDS.EQ.2) GO TO 5900
      IF (PPP.EQ.0.0) GO TO 5900
C
C   STATIC SOLUTION
C
      NNELP = NELP
      NELP = 1
      KZ = 2
      NCOUNT = 0
      NOK=0
      NTR=0
      MTRMAX = 10
      CPTIM1 = SEC(DUM)
 5500 CALL DERV2
      CALL RELAXP(NY2,YY,XX,ERR,NOK,NDBUG,NCOUNT)
      ICOUNT = ICOUNT + 1
      NTR=NTR+1
      MTR=(NTR-2)/(NY2+1)
      IF (MTR.EQ.(NTR-3)/(NY2+1)) GO TO 5550
      IF (NDBUG.EQ.0) GO TO 5500
      IF (NDERV.EQ.1) CALL LIST1
      IF (NDERV.EQ.2) CALL LIST2
 5550 IF (MTR.GT.MTRMAX) GO TO 6200
      IF (NOK.EQ.0) GO TO 5500
      IF (NOK.GE.2) GO TO 6300
      MTR=(NTR-1)/(NY2+1)
      NELP = NNELP
```

```
      J=1
      DO 5600 M=1,MG
      DO 5600 N=1,MB
      IF (MUSE(N,M).EQ.0) GO TO 5600
      U1(N,M)=XX(J)
      V1(N,M)=XX(J+MGMB)
      W1(N,M)=XX(J+MGMB2)
      J=J+1
 5600 CONTINUE
      IF (KDS.EQ.3 .AND. NDBUG.EQ.0) GO TO 5900
      CPTIM3 = SEC(DUM)
      CPT=CPTIM3-CPTIM1
      WRITE(6,8350) MTR,CPT
      IF (NDERV.EQ.1) CALL LIST1
      IF (NDERV.EQ.2) CALL LIST2
      GO TO 5900
C
C     DYNAMIC RESPONSE
C
 5700 IFIRST=0
      CPTIM1 = SEC(DUM)
      J=1
      KC = 0
      DO 5750 M=1,MG
      DO 5750 N=1,MB
      IF (MUSE(N,M).EQ.0) GO TO 5750
      XX(J)=U1(N,M)
      XX(J+MGMB) = V1(N,M)
      XX(J+MGMB2)=W1(N,M)
      VXO(J)=0.
      VXO(J+MGMB)=0.
      VXO(J+MGMB2)=0.
      J=J+1
 5750 CONTINUE
      SMAX=0.0
      DPRT=-0.5*DELTIM
      TIME=0.0
      KHIM = 1
      TF = TSTOP + .5*DELTIM
 5760 CALL DERV2
      CALL HIM (KHIM,NY2,DELTIM,TIME,VXO,XX,YY)
      ICOUNT = ICOUNT + 1
      IF (KERR.GT.0) GO TO 6400
      IF (TIME.LT.TF) GO TO 5760
      WRITE (6,11400) TIME
      IF (KDAM.EQ.2) GO TO 5800
      CRIT(1)=SMAX
      WRITE(6,8400) NTRIAL,NCASE,RTRIAL(1),SMAX,TMAX
      IF (NFLP .EQ.2) WRITE(6,8900) NREG
      IF (NTECO.EQ.1) WRITE(6,8500)
      IF (NTECO.EQ.2) WRITE(6,8500)
```

```
 5800 CPTIM3 = SEC(DUM)
      CPT = CPTIM3 - CPTIM1
      WRITE(6,9000) CPT
      IF (JFIRST.EQ.0) GO TO 5900
      NS=0
      DO 5850 L=1,LMAX
      IF (KY(L).GT.1) NS=NS+1
 5850 CONTINUE
      WRITE(6,9200) NS,LMAX
      IF (JSTRFT.EQ.0) GO TO 5900
      NSSTR=0
      DO 5880  LSTR=1,LMAXST
      IF (KYSTR(LSTR).GT.1) NSSTR=NSSTR+1
 5880 CONTINUE
      WRITE(6,9100)
      WRITE(6,9200) NSSTR,LMAXST
C
 5900 RETURN
C
C  ERROR MESSAGES
C
 6200 WRITE(6,8450) MTR
 6300 KERR = 1
      TIME = 0.
C
 6400 WRITE (6,11500) TIME
      RETURN
C
C  FORMAT STATEMENTS
C
 8350 FORMAT(26H1RESULTS OF STATIC PRELOAD/20H0NUMBER OF TRIALS = I5/
     115H NET CP TIME = F11.3)
 8400 FORMAT(17H0RESULTS OF TRIALI3,8H OF CASEI3/21H   RANGE, FT        =
     1 E15.8/21H   CRIT(1)          = E15.8/21H   TIME, SEC          = E15.8
     2)
 8450 FORMAT (35H0TOO MANY TRIALS IN STATIC SOLUTION/7H MTR = I4)
 8500 FORMAT(10H    TENSION)
 8600 FORMAT(14H    COMPRESSION)
 8900 FORMAT(25H    ELASTIC-PLASTIC REGIONI4)
 9000 FORMAT (33H0NET CP TIME FOR RESPONSE, SEC = F10.3)
 9100 FORMAT (21H0STRINGER CALAULATION)
 9200 FORMAT (1H0,I4,3H OF,I4,15H POINTS YIELDED)
11400 FORMAT(1H0//43H NORMAL DEPROSP STOP CONDITION AT T, SEC = E14.6)
11500 FORMAT (1H //32H0DEPROSP IS ABORTED AT T, SEC = E14.6)
      END
```

```
      SUBROUTINE RFIT(I,J,K,KSTR)
C     COMPUTE REACTIVE FORCES
      COMMON/CBLK1/  A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1   MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2   NBND,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK3/  GX(6),GXSTR(14),HGO(6),HGOSTR(14)
      COMMON/CBLK7/  BSTR,CN1,CN12,CN13,CN2,CN2STR,CN3,CN4,CN5,CN6,CN7,
     1   EL,EP,EPO,EPP,EPPSTR,H,HSTR,IFIRST,JFIRST,JSTRFT,LC,LCMAX,
     2   LCMAXS,LCSTR,NELP,SIGO,SIGO2,TNU,TNUSQ
      COMMON/CBLK10/ DWB(361),DWG(361),DWO(361),        U(361),
     1   UB(361),UG(361),V(361),VB(361),VG(361),W(361),WB(361),
     2   WBB(361),WG(361),WGB(361),WGG(361)
      COMMON/CBLK11/ CM11,CM11ST,CM12,CM22,CM33,DM11,DM11ST,DM12,DM22,
     1   DM33,FM11,FM12,FM22,FM33
      COMMON /CBLK14/ NBUSE(23,23),NRC,C1,C2,C3,C4,C5,C6,C7,
     1  DELX,DELT,    WGGG(44),WBBB(44),WGGB(44),WGBB(44),
     2  VRX(44),VRT(44),RR(4),ENX(44),ENT(44),NKP,KPG(46),KPB(46)
      COMMON            CN10,CN11,CN8,CN9,EPBO(1805),EPBOST(1380),ETT,EXT,
     1   EXX,EXXSTR,INZ(2),INZSTR(2),KSUMA(361),KSUMAS(231),KY(1805),
     2   KYSTR(1380),NUSE(23,23),STT(1805),SXT(1805),SXX(1805),
     3   SXXSTR(1380),S1A(361),S2A(361),S3A(361),S4A(361),S5A(361),
     4   S6A(361),S7A(230),S8A(230),UU(13,13),VV(13,13),WW(13,13),
     5   XB(23),XG(23),XKTT,XKXT,XKXX,XKXXST,X1A(361),X2A(361),X3A(361),
     6   X4A(361),X5A(361),X6A(361),X7A(230),X8A(230),ZA(2),ZASTR(2),
     7   ZB(2),ZBSTR(2),ZF(6),ZFSTR(14),ZG(6),ZGSTR(14),ZH(6),ZHSTR(14)
      NBC = NBUSE(J,I)
      IF (NDERV.EQ.2) GO TO 600
C     NDERV = 1.
      IF (NBC.GT.100) GO TO 200
      IF (NBC.GT.0) GO TO 100
      NBC = -NBC
      VRX(NBC) = C1*WGGG(NBC) + C2*WGBB(NBC)
      ENX(NBC)=CM11*X1A(K) + CM12*X2A(K)
      IF (I.EQ.1) VRX(NBC) = -VRX(NBC)
      GO TO 1200
C
  100 VRT(NBC) = C3*WBBB(NBC) + C4*WGGB(NBC)
      ENT(NBC)=CM22*X2A(K) + CM12*X1A(K)
      IF (J.EQ.1) VRT(NBC) = -VRT(NBC)
      GO TO 1200
C
  200 NBC = NBC - 100
      RR(NBC) = C5*WGB(K)*(-1.0)**(NBC/2)
      GO TO 1200
C
C     NDERV = 2.
C
C     ELASTIC-PLASTIC.
C
  600 SUM = 0.0
      SUM1 = 0.0
```

```
      SUMSTR = 0.0
      SUM1ST = 0.0
      JI = LBAR*(K-1)
      IF (NBC.GT.100) GO TO 1000
      IF (NBC.GT.0) GO TO 800
      NBC = -NBC
      JI1 = LBAR*(K-2)
      K2 = I*NBT + J
      IF (I.GT.1) K2 = (I-2)*NBT + J
      JI2 = LBAR*(K2 - 1)
      DELXX = DELX
      IF (I.EQ.1) DELXX = -DELX
      DO 700 KK = 1,LBAR
      L = JI + KK
      L1 = JI1 + KK
      L2 = JI2 + KK
      G1 = SXX(L)
      G11 = SXX(L2)
      G3 = SXT(L)
      G31 = SXT(L1)
      SUM = SUM + ((G11 - G1)/DELXX + 2.0*(G31 - G3)/DELT)*
     1          GX(KK)*HGO(KK)
  700 SUM1 = SUM1 + HGO(KK)*G1
      IF (IMASTR.EQ.0) GO TO 790
      JISTR = LBARST * (KSTR-1)
      K2STR = I*NSTR + KSTR
      IF (I.GT.1) K2STR = (I-2)*NSTR + KSTR
      JI2STR = LBARST * (K2STR-1)
      DO 750  KKSTR=1,LBARST
      LSTR = JISTR + KKSTR
      L2STR = JI2STR + KKSTR
      G1STR = SXXSTR(LSTR)
      G11STR = SXXSTR(L2STR)
      SUMSTR = SUMSTR + ((G11STR-G1STR)/DELXX) * GXSTR(KKSTR)
     1              * HGOSTR(KKSTR)
  750 SUM1ST = SUM1ST + HGOSTR(KKSTR)*G1STR
  790 VRX(NBC) =  C5*SUM/2.0 + (- HSTR**2/2.0)*SUMSTR/2.0
      IF (I.EQ.1) VRX(NBC) = -VRX(NBC)
      ENX(NBC) = H*SUM1/2.0 + HSTR*SUM1ST/2.0
      GO TO 1200
C
  800 K1 = K - 2
      IF (J.EQ.1) K1 = K
      JI1 = LBAR*K1
      DELTT = DELT
      IF (J.EQ.1) DELTT = -DELT
      JI2 = LBAR*((I-2)*NBT + J-1)
      DO 900 KK = 1,LBAR
      L = JI + KK
      L1 = JI1 + KK
      L2 = JI2 + KK
```

```
      G2 = STT(L)
      G22 = STT(L1)
      G3 = SXT(L)
      G32 = SXT(L2)
      SUM = SUM + ((G22 - G2)/DELTT + 2.0*(G32 - G3)/DELX)*
     1  GX(KK)*HGO(KK)
  900 SUM1 = SUM1 + HGO(KK)*G2
      VRT(NBC) =  C5*SUM/2.0
      IF (J.EQ.1) VRT(NBC) = -VRT(NBC)
      ENT(NBC) = H*SUM1/2.0
      GO TO 1200
C
 1000 NBC = NBC - 100
      DO 1100 KK=1,LBAR
      L = JI + KK
 1100 SUM = SUM + GX(KK)*HGO(KK)*SXT(L)
      RR(NBC) = C5*SUM*(-1.0)**(NBC/2)
 1200 RETURN
      END
```

```
      SUBROUTINE RELAXP (NEQ,RES,X,ERR,NOK,NPRINT,NCOUNT)
      DIMENSION RES(1),X(1),ERR(1)
      COMMON /CBLK12/ DELX(147),IP(147),PRES(147),PX(147),RRES(147),
     1   SIGX(147),XRES(147,147),XX1(147)
      DATA CON/5000./
      IF (NPRINT.NE.2) GO TO 40
      WRITE (5,50) (X(N),RES(N),N=1,NEQ)
   50 FORMAT (1H ,//4X,8H TRIAL X,10X,7HRESIDUE/(4X,E13.6,4X,E13.6))
   40 IF (NCOUNT.EQ.0 ) GO TO 10
      IF (NCOUNT.LE.NEQ) GO TO 14
      NCOUNT=0
      NQ=0
      NNQ=0
      DO  2  I=1,NEQ
      DX = X(I) - PX(I)
      IF (ABS(DX).LE.ERR(I)) NQ = NQ + 1
      IF (ABS(RES(I))-ABS(PRES(I)).GT.0.0)   NNQ=NNQ+1
    2 CONTINUE
      IF (NQ.EQ.NEQ) GO TO 100
      IF (NNQ.EQ.NEQ) GO TO 101
   10 DO 4  I=1,NEQ
      XX1(I)=X(I)
      RRES(I)=RES(I)
      DELX(I)=ABS(0.0001*X(I))
      IF (DELX(I).LT.ERR(I)) DELX(I)=ERR(I)
    4 CONTINUE
      GO TO 6
   14 DO 7  MM=1,NEQ
    7 XRES(MM,NCOUNT) = (RES(MM) - RRES(MM)) / DELX(NCOUNT)
      X(NCOUNT)=XX1(NCOUNT)
      IF (NCOUNT.EQ.NEQ) GO TO 8
    6 NCOUNT=NCOUNT+1
      X(NCOUNT)=X(NCOUNT)+DELX(NCOUNT)
      NOK=0
      RETURN
    8 DO 20  I=1,NEQ
   20 SIGX(I)=-RRES(I)
      CALL SOLVE (XRES,NEQ,147,0,IP,DET,SIGX)
      IF (NEQ.EQ.0) GO TO 15
      PROP=1.0
      DO 13 I=1,NEQ
      IF (ABS(SIGX(I)).LT.CON*ERR(I)) GO TO 13
      XPROP = CON*ERR(I)/ABS(SIGX(I))
      IF (XPROP.LT.PROP) PROP=XPROP
13    CONTINUE
      DO 12  I=1,NEQ
      X(I)=XX1(I)+SIGX(I)*PROP
      PX(I)=XX1(I)
   12 PRES(I)=RRES(I)
      NOK=0
      NCOUNT=NEQ+1
```

```
      RETURN
  100 NOK=1
      GO TO 11
  101 WRITE (6,55)
   55 FORMAT (32H0    SOLUTION DIVERGING IN RELAXPI)
   15 NOK = 2
   11 NCOUNT=0
      RETURN
      END
```

```
      FUNCTION SEC (DUM)
C     FIND ELAPSED CP TIME.
C
      CALL SECOND (SEC)
      RETURN
      END
```

```
      SUBROUTINE SIGMA (I,J,M,MSTR)
C
C     THIS S/R DETERMINES THE STRESS-STRAIN RELATIONSHIPS FOR
C       ELASTIC AND/OR PLASTIC RESPONSE.
C     SUBROUTINE COMPLETELY REVISED MARCH, 1976.
C
C     K - INDEX OF THE INTEGRATION POINT IN THE Z DIRECTION.
C     I - INDEX OF THE INTEGRATION POINT IN THE BETA DIRECTION.
C     J - INDEX OF THE INTEGRATION POINT IN THE GAMMA DIRECTION.
C     KSTR - INDEX OF THE INTEGRATION POINT IN THE STRINGER Z DIRECTION.
C
      COMMON/CBLK1/   A,IMASTR,KZ,LBAR,LBARST,LMAX,LMAXST,LOCSTR(6),MB,
     1    MBAR,MBSTR,MG,MGM(13),MGMB,MGMB2,MUSE(13,13),NB,NBAR,NBN(13),
     2    NBND,NBT,NDERV,NG,NGNB,NGNBT,NGT,NPLT,NSTR,NSYMB,NSYMG,PI
      COMMON/CBLK3/   GX(6),GXSTR(14),HGO(6),HGOSTR(14)
      COMMON/CBLK4/   NY2,VXO(147),XX(147),YY(147),
     1    AAU(49,49),AAW(49,49),BBU(49),BBW(49),IPU(49),IPW(49)
      COMMON   /CBLK6/   ALTT(1805),ALXT(1805),ALXX(1805),
     1    ALXXST(1380),BE1(1805),BE2(1805),BE3(1805),BE4(1380),
     2    EPB(1805),EPBSTR(1380),ETT1(1805),EXT1(1805),EXX1(1805),
     3    EXXST1(1380),SIGTT1(1805),SIGXT1(1805),SIGXX1(1805),
     4    SIGX1S(1380),TTNU(1805),TTNUST(1380)
      COMMON/CBLK7/   BSTR,CN1,CN12,CN13,CN2,CN2STR,CN3,CN4,CN5,CN6,CN7,
     1    EL,EP,EPO,EPP,EPPSTR,H,HSTR,IFIRST,JFIRST,JSTRFT,LC,LCMAX,
     2    LCMAXS,LCSTR,NELP,SIGO,SIGO2,TNU,TNUSQ
      COMMON/CNOVA/   CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1    KDAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NDBUG,NMASS,NTRIAL,
     2   PB(40),PDAM,PPP,PRINT,RFR,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3    ZZ1(9)
      COMMON            CN10,CN11,CN8,CN9,EPBO(1805),EPBOST(1380),ETT,EXT,
     1    EXX,EXXSTR,INZ(2),INZSTR(2),KSUMA(361),KSUMAS(230),KY(1805),
     2    KYSTR(1380),NUSE(23,23),STT(1805),SXT(1805),SXX(1805),
     3    SXXSTR(1380),S1A(361),S2A(361),S3A(361),S4A(361),S5A(361),
     4    S6A(361),S7A(230),S8A(230),UU(13,13),VV(13,13),WW(13,13),
     5    XB(23),XG(23),XKTT,XKXT,XKXX,XKXXST,X1A(361),X2A(361),X3A(361),
     6    X4A(361),X5A(361),X6A(361),X7A(230),X8A(230),ZA(2),ZASTR(2),
     7    ZB(2),ZBSTR(2),ZF(6),ZFSTR(14),ZG(6),ZGSTR(14),ZH(6),ZHSTR(14)
C
C
      DATA TOL/5.0E-3/
      DATA PANEL /10H   PANEL     /,
     1     STRING /10H   STRINGER/
C
      IF (IFIRST.GT.0) GO TO 300
C
C         INITIALIZATION ROUTINE FOR PANEL
C
      IFIRST = 1
      EPO=SIGO/EL
      EPP = 0.0
      CN2 = 0.0
```

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```
      SIGO2 = SIGO**2
      CN1 = (0.5 - TNU)/EL
      CN3 = 1.0/EL
      TNUSQ = TNU**2
      CN4 = (1.0 - TNUSQ)**2
      CN12 = (1.0 - TNU + TNUSQ)/CN4
      CN13 = (1.0 - 4.0*TNU + TNUSQ)/CN4
      CN4 = 0.75/((1.0 + TNU)**2)
      CN6 = EL/(1.0 - TNU**2)
      CN7 = EL*0.5/(1.0 + TNU)
      CN5 = 1.0/CN7
      LC = 0
      LCMAX = 100
      DO 100 L=1,LMAX
      IF (NELP.EQ.1) GO TO 70
      ALXX(L) = 0.0
      ALTT(L) = 0.0
      ALXT(L) = 0.0
      BE1(L) = 0.0
      BE2(L) = 0.0
      BE3(L) = 0.0
      TTNU(L) = TNU
   70 EPBO(L)=0.0
  100 KY(L) = 1
C
      IF (NSTR.EQ.0) GO TO 300
C
C          INITIALIZATION ROUTINE FOR STRINGERS
C
      EPPSTR = 0.0
      CN2STR = 0.0
      LCSTR = 0
      LCMAXS = 100
      DO 200  LSTR=1,LMAXST
      IF (NELP.EQ.1) GO TO 170
      ALXXST(LSTR) = 0.0
      BE4(LSTR) = 0.0
      TTNUST(LSTR) = TNU
  170 EPBOST(LSTR) = 0.0
  200 KYSTR(LSTR) = 1
C
C          START OF MAIN ROUTINE FOR PANEL CALCULATIONS
C
  300 KSUM = 0
C
      IJ = LBAR*(M-1)
C
C          LOOP FOR PANEL CALCULATIONS
C
      DO 3950 K=1,LBAR
      L = IJ + K
```

```
      H1 = ZF(K)
C
C     DETERMINE APPROPRIATE REGION.
C
      KEY  = KY(L)
      IF (KEY.GT.3) GO TO 350
      GO TO (400,600,700), KEY
  350 IF ((KEY+1)/2.EQ.KEY/2) GO TO 600
      GO TO 700
C
C     REGION 1.  ELASTIC CURVE.
C
  400 KSUM = KSUM + 1
      IF (KSUM.GT.1) GO TO 450
      D1 = CN5*(EXX + TNU*ETT)
      D2 = CN5*(ETT + TNU*EXX)
      D3 = CN7*EXT
      D4 = CN5*(XKXX + TNU*XKTT)
      D5 = CN5*(XKTT + TNU*XKXX)
      D6 = CN7*XKXT
      S1A(M) = D1
      S2A(M) = D2
      S3A(M) = D3
      S4A(M) = D4
      S5A(M) = D5
      S6A(M) = D6
  450 G1 = D1 + H1*D4
      G2 = D2 + H1*D5
      G3 = D3 + H1*D6
      SIGBD =  G1*(G1 - G2) + G2**2 + 3.0*G3**2
      IF (NFLP.EQ.2) GO TO 470
      EPBO(L)=SIGBD
      GO TO 3000
  470 IF (SIGBD.GE.SIGO2) GO TO 500
      EPBO(L)      = SIGBD
      GO TO 3000
C
C     LINEARLY INTERPOLATE ON SIGMA BAR TO CORRECT FOR OVERSHOOT.
C
  500 KY(L) = KEY + 1
      SQSIG = SQRT(SIGBD)
      B2 = SQRT(EPBO(L))
      B1 = (SIGO - B2)/(SQSIG - B2)
      G1 = SXX(L)      + B1*(G1 - SXX(L))
      G2 = STT(L)      + B1*(G2 - STT(L))
      G3 = SXT(L)      + B1*(G3 - SXT(L))
      SIGXX1(L)      = G1
      SIGTT1(L)      = G2
      SIGXT1(L)      = G3
      T1  = CN3*(G1 - TNU*G2)
      T2  = CN3*(G2 - TNU*G1)
```

```
      T3  = CN5*G3
      EXX1(L) = T1
      ETT1(L) = T2
      EXT1(L) = T3
      EPBD = SQRT(CN12*(T1**2 + T2**2) - CN13*T1*T2 + CN4*T3**2)
      EPB(L)      = EPBD
      EPBO(L)      = EPBD
      IF (JFIRST.EQ.0) JFIRST = 1
      GO TO 3000
C
C
C     REGIONS 2 AND 4.  PLASTIC LOADING.
C
  600 EPBDP = EPB(L)
      H2 = EXX + H1*XKXX - BE1(L)
      H3 = ETT + H1*XKTT - BE2(L)
      H4 = EXT + H1*XKXT - BE3(L)
      CN2 = TTNU(L)
      II = 0
  610 II = II + 1
      CN22 = CN2**2
      EPBD = SQRT(((1.0 - CN2 + CN22)*(H2**2 + H3**2) -
     1  (1.0 - 4.0*CN2 + CN22)*H2*H3)/(1.0 - CN22)**2 +
     2  0.75*H4**2/(1.0 + CN2)**2)
      DELEP = EPBD - EPBO(L)
      EPP = (EP*DELEP + EL*EPBO(L))/EPBD
      IF (TNU.GT.0.0) CN2 = .5 - EPP*CN1
      IF (ABS(CN2-TTNU(L)).LT.0.0005) GO TO 620
      IF (II.GT.20) GO TO 615
      TTNU(L) = CN2
      GO TO 610
  615 WRITE (6,5500) CN2,TTNU(L),TIME,PANEL
      GO TO 4100
  620 CN2 = TTNU(L)
      IF (EPBD.LE.EPBDP) GO TO 650
  630 EPB(L) = EPBD
      IF (EPP.GT.EL.OR.EPP.LT.EP) GO TO 4000
      S1 = EPP/(1.0 - CN2**2)
      S2 = 0.5*EPP/(1.0 + CN2)
      G1 = S1*(H2 + CN2*H3) + ALXX(L)
      G2 = S1*(H3 + CN2*H2) + ALTT(L)
      G3 = S2*H4 + ALXT(L)
      GO TO 3000
C
C     SECOND TEST FOR UNLOADING IN EITHER REGION 2 OR 4.
C
  650 Q1=X1A(M)-EXX1(L) + H1*X4A(M)
      Q2=X2A(M)-ETT1(L) + H1*X5A(M)
      Q3=X3A(M)-EXT1(L) + H1*X6A(M)
      IF (EP.EQ.0.0)GO TO 660
      P1=SXX(L)-SIGXX1(L) + ALXX(L)
```

```
      P2=STT(L)-SIGTT1(L) + ALTT(L)
      P3=SXT(L)-SIGXT1(L) + ALXT(L)
      GO TO 670
  660 P1=0.0
      P2=0.0
      P3=0.0
  670 E1=Q1 - H2
      E2=Q2 - H3
      E3=Q3 - H4
      G1=P1-CN6*(E1+TNU*E2)
      G2=P2-CN6*(E2+TNU*E1)
      G3=P3-CN7*E3
      A1=G1-P1
      A2=G2-P2
      A3=G3-P3
      SIGBD=A1*(A1-A2)+A2**2+3.0*A3**2
      IF (SIGBD.GE.SIGO2.AND.DELEP.GE.0.0) GO TO 530
C
      KY(L)=KEY+1
      TTNU(L)=TNU
      EPBO(L)=SIGBD
      BE1(L)=Q1 + BE1(L)
      BE2(L)=Q2 + BE2(L)
      BE3(L)=Q3 + BE3(L)
      IF (EP.EQ.0.)GO TO 3000
      ALXX(L)=P1
      ALTT(L)=P2
      ALXT(L)=P3
      GO TO 3000
C
C
C     REGION 3.  ELASTIC UNLOADING - RELOADING.
C
  700 E1 = BE1(L) - EXX - H1*XKXX
      E2 = BE2(L) - ETT - H1*XKTT
      E3 = BE3(L) - EXT - H1*XKXT
      C1 = ALXX(L)
      C2 = ALTT(L)
      C3 = ALXT(L)
      G1 = C1 -               CN6*(E1  + TNU*E2)
      G2 = C2 -               CN6*(E2 + TNU*E1)
      G3 = C3 -               CN7*E3
      A1 = G1 - C1
      A2 = G2 - C2
      A3 = G3 - C3
      SIGBD = A1*(A1 - A2) + A2**2 + 3.0*A3**2
      IF (SIGBD.GT.SIGO2)GO TO 800
      EPBO(L)=SIGBD
      GO TO 3000
C
C     LINEARLY INTERPOLATE ON SIGMA BAR TO CORRECT FOR OVERSHOOT.
```

```
C
  800 B2 = SQRT(EPBO(L))
      SQSIG = SQRT(SIGBD)
      IF (B2.GT.SIGO) GO TO 840
      NC = 0
  820 B1 = (SQSIG - SIGO)/(SQSIG - B2)
      NC = NC + 1
      IF (NC.GT.5) GO TO 830
      DEL1 = B1*(G1 - SXX(L))
      DEL2 = B1*(G2 - STT(L))
      DEL3 = B1*(G3 - SXT(L))
      G1 = G1 - DEL1
      G2 = G2 - DEL2
      G3 = G3 - DEL3
      A1 = G1 - ALXX(L)
      A2 = G2 - ALTT(L)
      A3 = G3 - ALXT(L)
      SQSIG = SQRT(A1*(A1-A2) + A2**2 + 3.0*A3**2)
      IF (ABS(SQSIG-SIGO)/SIGO.GT.TOL) GO TO 820
      GO TO 835
  830 WRITE(6,5700) NC,K,I,J,KEY,SQSIG,B1,B2,TIME,PANEL
      LC = LC + 1
      IF (LC.GT.LCMAX) GO TO 4100
  835 CONTINUE
      DEL1 = G1 - SXX(L)
      DEL2 = G2 - STT(L)
      DEL3 = G3 - SXT(L)
      T1 = X1A(M) + CN3*(DEL1 - TNU*DEL2) + H1*X4A(M)
      T2 = X2A(M) + CN3*(DEL2 - TNU*DEL1) + H1*X5A(M)
      T3 = X3A(M) + CN5*DEL3 + H1*X6A(M)
      GO TO 880
  840 WRITE(6,5200) K,I,J,KEY,TIME,B2,SQSIG,PANEL
      T1 = EXX + H1*XKXX
      T2 = ETT + H1*XKTT
      T3 = EXT + H1*XKXT
      LC = LC + 1
      IF (LC.GT.LCMAX) GO TO 4100
  880 EXX1(L) = T1
      ETT1(L) = T2
      EXT1(L) = T3
      H2 = T1 - BE1(L)
      H3 = T2 - BE2(L)
      H4 = T3 - BE3(L)
      EPBD = SQRT(CN12*(H2**2 + H3**2) - CN13*H2*H3 + CN4*H4**2)
      EPBO(L) = EPBD
      EPB(L) = EPBD
      SIGXX1(L)      = G1
      SIGTT1(L)      = G2
      SIGXT1(L)      = G3
      KY(L) = KEY + 1
      GO TO 3000
```

```
C
C        LAST PART OF PANEL LOOP
C
 3000 SXX(L)      = G1
      STT(L)      = G2
      SXT(L)      = G3
 3050 CONTINUE
      KSUMA(M) = KSUM
C
      IF (IMASTR.EQ.0) GO TO 3999
C
C
C      START OF ROUTINE FOR STRINGER CALCULATIONS
C
      KSUMST = 0
      IJSTR = LBARST*(MSTR-1)
C
C
C        LOOP FOR STRINGER CALCULATIONS
C
      DO 3950  KSTR=1,LBARST
      LSTR = IJSTR + KSTR
      H1STR = ZESTR(KSTR)
C
      KEYSTR = KYSTR(LSTR)
      IF (KEYSTR.GT.3) GO TO 3100
      GO TO (3200,3500,3700), KEYSTR
 3100 IF ((KEYSTR+1)/2.EQ.KEYSTR/2) GO TO 3500
      GO TO 3700
C
C
C        REGION 1:  ELASTIC
C
 3200 KSUMST = KSUMST + 1
      IF (KSUMST.GT.1) GO TO 3250
      D7 = EL*EXXSTR
      D8 = EL*XKXXST
      S7A(MSTR) = D7
      S8A(MSTR) = D8
 3250 G4 = D7 + H1STR*D8
      SIGBDS = G4*G4
      IF (NELP.EQ.2) GO TO 3270
      EPBOST(LSTR) = SIGBDS
      GO TO 3900
 3270 IF (SIGBDS.GE.SIG02) GO TO 3300
      EPBOST(LSTR) = SIGBDS
      GO TO 3900
C
C       LINEARLY INTERPOLATE ON SIGMA BAR TO CORRECT FOR OVERSHOOT
C
 3300 KYSTR(LSTR) = KEYSTR + 1
      SQSIGS = SQRT(SIGBDS)
```

```
      B4 = SQRT(EPBOST(LSTR))
      B3 = (SIGO - B4)/(SQSIGS - B4)
      G4 = SXXSTR(LSTR) + B3*(G4 - SXXSTR(LSTR))
      SIGX1S(LSTR) = G4
      T4 = CN3*G4
      EXXST1(LSTR) = T4
      EPBDST = ABS(T4)
      EPBSTR(LSTR) = EPBDST
      EPBOST(LSTR) = EPBDST
      IF (JSTRFT.EQ.0) JSTRFT = 1
      GO TO 3900
C
C
C          REGIONS 2 AND 4:  PLASTIC LOADING
C
 3500 EPBDPS = EPBSTR(LSTR)
      H5 = EXXSTR + H1STR*XKXXST - BE4(LSTR)
      CN2STR = TTNUST(LSTR)
      IISTR = 0
 3510 IISTR = IISTR + 1
      CN2ST2 = CN2STR**2
      EPBDST = ABS(H5)
      DELEPS = EPBDST - EPBOST(LSTR)
      EPPSTR = (EP*DELEPS + EL*EPBOST(LSTR))/EPBDST
      IF ( TNJ.GT.0.0) CN2STR = 0.5 - EPPSTR*CN1
      IF (ABS(CN2STR-TTNUST(LSTR)).LT.0.0005) GO TO 3520
      IF (IISTR.GT.20) GO TO 3515
      TTNUST(LSTR) = CN2STR
      GO TO 3510
 3515 WRITE (6,5500) CN2STR,TTNUST(LSTR),TIME,STRING
      GO TO 4090
 3520 CN2STR = TTNUST(LSTR)
      IF (EPBDST.LE.EPBDPS) GO TO 3550
 3530 EPBSTR(LSTR) = EPBDST
      IF ( EPPSTR.GT.EL .OR. EPPSTR.LT.EP) GO TO 4050
      S3 = EPPSTR
      G4 = S3*H5 + ALXXST(LSTR)
      GO TO 3900
C
C          SECOND TEST FOR UNLOADING
C
 3550 Q4 = X7A(MSTR) - EXXST1(LSTR) + H1STR*X8A(MSTR)
      IF (EP.EQ.0.0) GO TO 3560
      P4 = SXXSTR(LSTR) - SIGX1S(LSTR) + ALXXST(LSTR)
      GO TO 3570
 3560 P4 = 0.0
 3570 E4 = Q4 - H5
      G4 = P4 - EL*E4
      A4 = G4 - P4
      SIGBDS = A4*A4
      IF (SIGBDS.GE.SIGO2 .AND. DELEPS.GE.0.0) GO TO 3530
```

```
      KYSTR(LSTR) = KEYSTR + 1
      TTNUST(LSTR) = TNU
      EPBOST(LSTR) = SIGBDS
      BE4(LSTR) = Q4 + BE4(LSTR)
      IF (EP.EQ.0.0) GO TO 3900
      ALXXST(LSTR) = P4
      GO TO 3900
C
C
C          REGION 3:  ELASTIC UNLOADING--RELOADING
C
 3700 E4 = BE4(LSTR) - EXXSTR - H1STR*XKXXST
      C4 = ALXXST(LSTR)
      G4 = C4 - EL*E4
      A4 = G4 - C4
      SIGBDS = A4*A4
      IF (SIGBDS.GT.SIGO2) GO TO 3800
      EPBOST(LSTR) = SIGBDS
      GO TO 3900
C
C          LINEARLY INTERPOLATE ON SIGMA BAR TO CORRECT FOR OVERSHOOT
C
 3800 B4 = SQRT(EPBOST(LSTR))
      SQSIGS = SQRT(SIGBDS)
      IF (B4.GT.SIGO) GO TO 3840
      NCSTR = 0
 3820 B3 = (SQSIGS - SIGO)/(SQSIGS - B4)
      NCSTR = NCSTR + 1
      IF (NCSTR.GT.10) GO TO 3830
      DEL4 = B3*(G4 - SXXSTR(LSTR))
      G4 = G4 - DEL4
      A4 = G4 - ALXXST(LSTR)
      SQSIGS = A4
      IF (ABS(SQSIGS-SIGO)/SIGO .GT. TOL) GO TO 3820
      GO TO 3835
 3830 WRITE (6,5700) NCSTR,KSTR,I,J,KEYSTR,SQSIGS,B3,B4,TIME,STRING
      LCSTR = LCSTR + 1
      IF (LCSTR.GT.LCMAXS) GO TO 4090
 3835 CONTINUE
      DEL4 = G4 - SXXSTR(LSTR)
      T4 = X7A(MSTR) + DEL4/EL + H1STR*X8A(MSTR)
      GO TO 3880
 3840 WRITE (6,5200) KSTR,I,J,KEYSTR,TIME,B4,SQSIGS,STRING
      T4 = EXXSTR + H1STR*XKXXST
      LCSTR = LCSTR + 1
      IF (LCSTR.GT.LCMAXS) GO TO 4090
 3880 EXXST1(LSTR) = T4
      H5 = T4 - BE4(LSTR)
      EPBOST = ABS(H5)
      EPBOST(LSTR) = EPBOST
      EPBSTR(LSTR) = EPBOST
```

```
      SIGX1S(LSTR) = S4
      KYSTR(LSTR) = KEYSTR + 1
      GO TO 3900
C
C
C           LAST PART OF STRINGER LOOP
C
 3900 SXXSTR(LSTR) = S4
 3950 CONTINUE
      KSUMAS(MSTR) = KSUMST
C
C
C               CALCULATIONS COMPLETE -- RETURN TO DERV2
C
C
 3999 RETURN
C
C
C
C     ERROR RETURN.
C
 4000 WRITE (6,5300) EPP,K,I,J,TIME,EPBD,EPBDP,EPBD(L),PANEL
      GO TO 4100
C
 4050 WRITE (6,5300) EPPSTR,KSTR,I,J,TIME,EPBDST,EPBDPS,EPBOST(LSTR),
     1      STRING
 4090 WRITE (6,5100)
C
 4100 WRITE (6,5400)
      KERR = 1
      RETURN
C
 5100 FORMAT (21H0STRINGER CALCULATION)
 5200 FORMAT (22H IMMEDIATE RELOADING   ,4I3,3E15.6,A10)
 5300 FORMAT (28H0EPP IS OUT OF RANGE, EPP = E14.6/
     1  3I3,4E15.6,A10)
 5400 FORMAT (21H0SOLUTION IS UNSTABLE)
 5500 FORMAT (26H VALUE OF NU WONT CONVERGE,2E15.6,15H   TIME, SEC =
     1  E15.6,A10)
 5700 FORMAT (38H CAN NOT TOTALLY CORRECT FOR OVERSHOOT/5I5,4E15.6,A10)
      END
```

```
      SUBROUTINE SOLVE (A,N,NDIM,NDET,IP,DET,B)
C
C     A    = ORIGINAL MATRIX.
C     N    = ACTUAL DIMENSIONS OF A.
C     NDIM = DECLARED DIMENSION OF A IN CALLING PROGRAM.
C     NDET = DETERMINENT CODE.
C            0 = NOT CALCULATED.
C            1 = CALCULATED.
C     IP   = INDEX OF K-TH PIVOT ROW.
C     DET  = DETERMINENT OF A.
C     B    = RIGHT HAND SIDE VECTOR.
C
      DIMENSION A(NDIM,NDIM),IP(NDIM),B(NDIM)
C
      IP(N)=1
      DO 6 K=1,N
      IF (K.EQ.N) GO TO 5
      KP1=K+1
      M=K
      DO 1 I=KP1,N
      IF (ABS(A(I,K)).GT.ABS(A(M,K))) M=I
    1 CONTINUE
      IP(K)=M
      IF (M.NE.K) IP(N)=-IP(N)
      T=A(M,K)
      A(M,K)=A(K,K)
      A(K,K)=T
      IF (T.EQ.0.0) GO TO 5
      DO 2 I=KP1,N
    2 A(I,K)=-A(I,K)/T
      DO 4 J=KP1,N
      T=A(M,J)
      A(M,J)=A(K,J)
      A(K,J)=T
      IF (T.EQ.0.0) GO TO 4
      DO 3 I=KP1,N
    3 A(I,J)=A(I,J)+A(I,K)*T
    4 CONTINUE
    5 IF (A(K,K).EQ.0.0) GO TO 15
    6 CONTINUE
      IF (NDET.EQ.0) GO TO 11
      DET=IP(N)
      DO 10 I=1,N
   10 DET=DET*A(I,I)
   11 IF (N.EQ.1) GO TO 14
      NM1=N-1
      DO 12 K=1,NM1
      KP1=K+1
      M=IP(K)
      T=B(M)
      B(M)=B(K)
```

```
      B(K)=T
      DO 12 I=KP1,N
   12 B(I)=B(I)+A(I,K)*T
      DO 13 KB=1,NM1
      KM1=N-KB
      K=KM1+1
      B(K)=B(K)/A(K,K)
      T=-B(K)
      DO 13 I=1,KM1
   13 B(I)=B(I)+A(I,K)*T
   14 B(1)=B(1)/A(1,1)
      GO TO 17
   15 WRITE(6,16)
   16 FORMAT (29HOSINGULAR MATRIX IN S/R SOLVE)
      N = 0
   17 RETURN
      END
```

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The major objective of this study was to investigate the effects of axial stiffening of cylindrical shells subject to transverse blast loadings. Two existing methods for predicting dynamic response of cylindrical shells were modified to include axial stiffening. A semi-analytical energy method was chosen as a "first cut" design predictor and tables of normalized deflection versus external energy imparted to the structure are presented.

next page

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20. In addition a more detailed analytical energy method was modified to include axial stiffening. In both cases the stiffeners were introduced by simply adding terms to the kinetic and potential energy terms of the basic shell equations rather than introducing membrane-bending coupling by use of more complicated anisotropic constitutive relations. The primary results of both methods indicate that the effect of axially stiffening a cylindrical shell using stiffeners typical of those in aerospace applications is very small. Both methods have been incorporated into computer algorithms which allow an investigator to determine failure modes of blast loaded shells either by an engineering approach or a more sophisticated detailed approach.